South Dakota Water Research Institute
Annual Technical Report
FY 2014

Introduction

South Dakota Water Resources Institute’s (SDWRI) programs are administered through the College of Agricultural and Biological Sciences at South Dakota State University (SDSU). Dr. Van Kelley has served as the Director for the Institute since August 1, 2000. Dr. Kelley is also the head of the Agricultural and Biological Engineering Department. In addition to the Director, the Institute’s programs are administered and executed by a staff consisting of an Assistant Director, a Program Manager, a Program Assistant, an Assistant Professor and a Research Associate. During FY 2014 the SDWRI financially supported, through its base funding or through externally funded projects, two PhD students, two MS students and two undergraduate research assistants.

The annual base grant from the United States Geological Survey (USGS) and a South Dakota legislative appropriation form the core of the SDWRI budget. The core budget is supplemented by research grants from a state and federal agencies as well as private organizations and industry interested in specific water-related issues.

The mission of the South Dakota Water Resources Institute is to address the current and future water resource needs of the people, industry and the environment through research, education, and service. To accomplish this mission, SDWRI provides leadership by coordinating research and training at South Dakota State University and other public educational institutions and agencies across the state in the broad area of water resources. Graduate research training, technology transfer, and information transfer are services which are provided through the Institute.

This report is a summary of the activities conducted by the SDWRI during the period March 1, 2014 through February 28, 2015.

Research Program Introduction

Water is one of the most important resources in South Dakota. Together with the state's largest industry, agriculture, it will play an important role in the economic future of the state. Enhancement of the agricultural industry and allied industries, the industrial base and, therefore, the economy of South Dakota all depend on compatible development of our water resources.

During FY 2014, the South Dakota Water Resources Institute (SDWRI) used its 104B Grant Program fund to conduct research of local, state, regional, and national importance addressing a variety of water problems in the state and the upper Midwest region.

The SDWRI 104B External Review Panel reviewed 10 grant applications and recommended 3 projects for funding that addressed research priorities that had a good chance of success, and would increase our scientific knowledge. The projects were titled:

Nutrient Removal from Agricultural Subsurface Drainage Using Denitrification Bioreactors and Phosphate Adsorbents PI’s G. Hua, C. Schmit, J. Kjaersgaard, C. Hay, South Dakota State University

Evaluating Nutrient Best Management Practices to Conserve Water Quality PI’s L. Ahiablame, S. Kumar, South Dakota State University

Source water implications associated with the current Black Hills Mountain Pine-Beetle Infestation PI’s J. Stone, J. Stamm, South Dakota School of Mines and Technology

In addition, the following projects selected for funding during FY2012 and FY2013 were previously granted no-cost project extensions:

Subsurface Drainage Impacts on Evapotranspiration and Water PI’s C. Hay, J. Kjaersgaard, T. Trooien, South Dakota State University and G. Sands, University of Minnesota

Evaluating the Nitrate-Removal Effectiveness of Denitrifying Bioreactors PI’s J. Kjaersgaard, C. Hay, T. Trooien, South Dakota State University.

Evaluation of Wastewater produced in biomass pyrolysis PI’s L, Wei, T, Trooien, South Dakota State University

Progress and completion reports for these projects are enclosed on the following pages.

Subsurface Drainage Impacts on Evapotranspiration and Water

Basic Information

Title:	Subsurface Drainage Impacts on Evapotranspiration and Water
Project Number:	2012SD212B
Start Date:	3/1/2012
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	First
Research Category:	Climate and Hydrologic Processes
Focus Category:	Hydrology, Agriculture, Water Quantity
Descriptors:	
Principal Investigators:	Christopher Hay, Jeppe H Kjaersgaard, Todd P. Trooien

Publications

1. Evapotranspiration for fields with and without tile drainage. To be submitted to Transactions of the American Society of Agricultural and Biological Engineers by 31 Dec 2014.
2. Khand, K., C. Hay, J. Kjaersgaard, and T. Trooien. 2013. Subsurface drainage impacts on evapotranspiration (ET). Eastern South Dakota Water Conference. Brookings, S.D. 30 Oct.
3. Khand, K., C. Hay, J. Kjaersgaard, and T. Trooien. 2013. Subsurface drainage impacts on evapotranspiration (ET). Eastern South Dakota Water Conference. Brookings, S.D. 30 Oct.
4. Khand, K., J. Kjaersgaard, C. Hay, and X. Jia. 2014. Estimating evapotranspiration from drained and undrained agricultural fields using remote sensing. ASABE Paper No. 1829687. St. Joseph, Mich.: ASABE.
5. Kjaersgaard, J., K. Khand, C. Hay, and X. Jia. 2014. Estimating evapotranspiration from fields with and without tile drainage using remote sensing. World Environmental and Water Resources Congress 2014: pp. 1745-1753. doi: 10.1061/9780784413548.173
6. Khand, K. (lead author). Evapotranspiration for fields with and without tile drainage. To be submitted to Transactions of the American Society of Agricultural and Biological Engineers in 2015.
7. Khand, K., J. Kjaersgaard, and C. Hay. 2014. Evaluating impacts of subsurface drainage on evapotranspiration using remote sensing. 15th Annual Iowa-Minnesota-South Dakota Drainage Research Forum, Ames, Iowa. 18 Nov. [Invited presentation—Hay]
8. Kjaersgaard, J., K. Khand, and C. Hay. 2014. Estimating impacts of tile drainage on crop consumptive water use. Western South Dakota Hydrology Conference, Rapid City, S.D. 9 April. [Oral presentation—Kjaersgaard]

Project Completion Report

Project Title: Subsurface Drainage Impacts on Evapotranspiration and Water Yield

PIs: Christopher Hay, Jeppe Kjaersgaard, Todd Trooien, and Gary Sands

Recipient Organization: South Dakota State University

Project Period: 1 March 2012 to 28 February 2015

Reporting Period: 1 March 2012 to 28 February 2015

Submission Date: 21 May 2015

Summary

Subsurface (tile) drainage is a common water management practice on poorly drained agricultural soils to provide for more timely field operations and improved productivity. Artificial subsurface drainage systems may alter the field water balance by changing the timing and rate of subsurface water flow. The objective of this study was to examine the impact of subsurface drainage on evapotranspiration (ET) at the field scale. The study was conducted for four growing seasons split between corn and soybean at three different sites in southeast North Dakota, southwest Minnesota, and southeast South Dakota. The METRIC (Mapping Evapotranspiration at high Resolution with Internalized Calibration) model was applied to estimate ET at high resolution (30 m) from areas with and without subsurface drainage. At three of the four site years, there was no significant difference in ET between drained and undrained areas. Differences in ET were greater for soybean than for corn and were greater in the spring. However, insect damage confounded the results for soybean at the Minnesota site.

Background

Subsurface drainage has increased dramatically in eastern South Dakota with increases in precipitation, commodity prices, and land prices. Subsurface drainage improves agricultural production by increasing yields and reducing risk, but there are concerns about its environmental impacts. A key concern is to what extent does subsurface drainage contribute to downstream flow alterations and flooding through changes in the amount and timing of water leaving the field. Changes in evapotranspiration (ET), as a result of drainage, are a primary determinant of the hydrologic alterations from subsurface drainage. However, the impacts of drainage on ET are not yet well understood. Lack of such knowledge is an important problem, because without it, we are limited in our ability to accurately quantify the impacts of subsurface drainage on watershed hydrology and flooding.

The overall goal of this project was to develop a method to account for the impact of yield reductions from poor drainage on evapotranspiration in drainage model simulations. Our central hypothesis, based on water productivity functions that relate crop yield and ET, was that current drainage model simulations overestimate ET under undrained or poorly drained conditions. The rationale for the proposed research was that once we are able to accurately simulate ET under undrained and poorly drained conditions, we can then better estimate the impacts that subsurface drainage development will have on hydrology. Our contribution here was expected to be an improved understanding of the impacts of subsurface drainage on ET. Once such knowledge is available, we can better evaluate the hydrologic impacts of increased subsurface drainage in eastern South Dakota.

The objectives for this research were:

1. Develop a weather dataset from existing weather monitoring sites for use in calculating reference ET at sites where onsite data and limited data are available.
2. Compare ET between drained and undrained fields using the METRIC model for estimating ET based on satellite remote sensing imagery.
3. Compare the METRIC estimated ET to ground-based measured ET for the site where these data were available.

Accomplishments

Major Activities

Study Site Selection

Three study sites were chosen based on the condition of having subsurface drained and undrained fields with the same cropping system and similar management and soils in close proximity. Study years were chosen based on data availability. The location of the three sites chosen were:

1. Richland County, ND near Fairmount
2. Redwood County, MN near Tracy
3. Lincoln County, SD near Lennox

The Richland County, ND site had a total area of 44 ha, of which 22 ha had subsurface drainage and the other 22 ha was undrained. Two years were chosen for analysis, 2009 (corn) and 2010 (soybean). The Redwood County, MN site had two proximate fields. A 13.7 ha field was subsurface drained, and a 14.6 ha field did not yet have subsurface drainage installed. There was one study year, 2008 (soybean), available at this site. The Lincoln County, SD site was 28 ha with 15 ha drained and 13 ha undrained. The 2013 (corn) growing season was used for this site.

Model Selection

The METRIC (Mapping Evapotranspiration at high Resolution with Internalized Calibration) was chosen as the remote sensing-based model for estimating actual ET. METRIC estimates ET as a residual of the land surface energy balance. METRIC uses satellite imagery to estimate water use with high resolution (30 m). The METRIC procedure uses the visible, near-infrared and thermal infrared bands from satellite images and ground-based weather data to calculate ET on a pixel by pixel basis. This allowed us to compare crop consumptive use from fields with and without subsurface drainage. The METRIC model requires cloud-free Landsat imagery, digital elevation model data, land use data, and ground-based meteorological data.

Input Data Collection and Processing

Landsat Imagery

The METRIC procedure requires cloud-free Landsat imagery as the primary input. The selection of Landsat images was made primarily by visual inspection of each image for cloud cover. At least one image was taken from either Landsat 5 or Landsat 7 or Landsat 8 for each month of the growing season for the study years at each location. Images from Landsat 7 were given low priority due to failure of the scan line corrector (SLC), forming a zig-zag pattern at both edges of the image along the satellite ground track. Only images having clear study sites from Landsat 7 were selected when cloud-free Landsat 5 or 8 images were not available. For Site 1, seven images were selected for year 2009, and eight images were selected for year 2010 from both Landsat 5 and Landsat 7. For Site 2, four images were selected from Landsat 5 and Landsat 7 for year 2008. For Site 3, six images were selected from Landsat 7 and Landsat 8 for study year 2013.

Meteorological Data

To obtain the best results, the METRIC procedure requires hourly or shorter interval weather information. These data were obtained from a weather station installed at the study field site or from nearby weather stations. Air temperature, solar radiation, humidity, and wind speed data are required to estimate hourly reference ET, and precipitation is required for calculating the daily soil water balance. Reference ET was calculated using the ASCE Standardized Reference ET Equation.

For the Fairmount, ND site, hourly weather data were taken from the North Dakota Agricultural Weather Network (NDAWN) weather station located at Wahpeton ND, which is about 18 miles north from our study site. Daily rainfall data were taken from a rain gauge installed adjacent to the study site. Weather data for Site 3 (near Lennox, SD) were taken from the nearest SD Mesonet weather station located near Beresford, SD, which is about 20 miles south of the study site.

For Site 2 (near Tracy, MN), 20-minute interval weather data for selected satellite image dates were taken from the Automated Surface Observation System (ASOS) weather station located at Tracy, MN, which is about 9 miles southwest of the study site. Daily rainfall data were taken from the Global Historical Climatology Network (GHCN) weather station located at Tracy MN, and the missing data were filled from the ASOS Tracy weather station. Daily weather data were taken from the Southwest Research & Outreach Center (SWROC) weather station located at Lamberton, MN (except humidity), due to considerable missing data for days to weeks periods during the growing season from the ASOS weather station at Tracy. Humidity data were not available at SWROC, so the average dew point temperature was taken from Tracy ASOS weather station after making a homogeneity test with daily minimum temperature available at

SWROC. Missing values for average dew point temperature from Tracy were back-filled by developing a relationship with minimum temperature from SWROC.

Crop Coefficient and ET Estimation

METRIC processing was carried out to obtain instantaneous EToF (fraction of reference ET) maps (synonymous to crop coefficient) for all selected images during the growing season of considered yeas for all study sites. EToF values incorporates the plant characteristics, soil water availability to fulfill the atmospheric demand, planting density, fertilizers and pesticides, plant diseases and other affecting factors which may limit the potential crop ET. The extrapolation of instantaneous EToF values to 24-hour period and days between the image dates was carried out by cubic spline interpolation between the satellite image dates. Estimation of daily crop ET was obtained by multiplication of estimated daily EToF values with respective grass based reference ET. Daily averaged EToF pixel for areas representing drained and undrained conditions were multiplied with reference ET to get the daily crop ET values. Total ET was calculated by summing the daily ET values throughout the length of desired period or season.

Significant Results

Site 1: Fairmount, ND

2009 Corn

There was less than 0.5 mm/day difference in corn ET for all image dates and over the entire growing season (Figure 1). Overall, ET from the drained area was 3 mm greater ET from the drained area (463 mm) compared to the undrained area (460 mm) for the 2009 growing season. Therefore, there was no significant difference in ET between the drained and undrained areas.

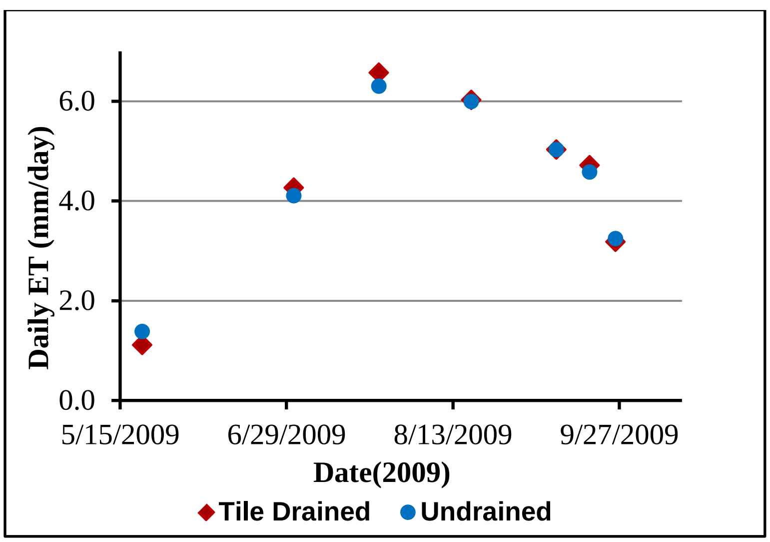


Figure 1. Daily corn ET estimates from drained and undrained areas for selected satellite image dates for year 2009.

2010 Soybean

For the 2010 growing season, there was generally less than 1 mm/day difference in soybean ET between the drained and undrained areas (Figure 2). However, there was a 1.76 mm/day difference for the May 17 image date. There was approximately 10% greater ET from the undrained area (567 mm) than from the drained area (514 mm) for the growing season. Nevertheless the differences in ET were not statistically significant.

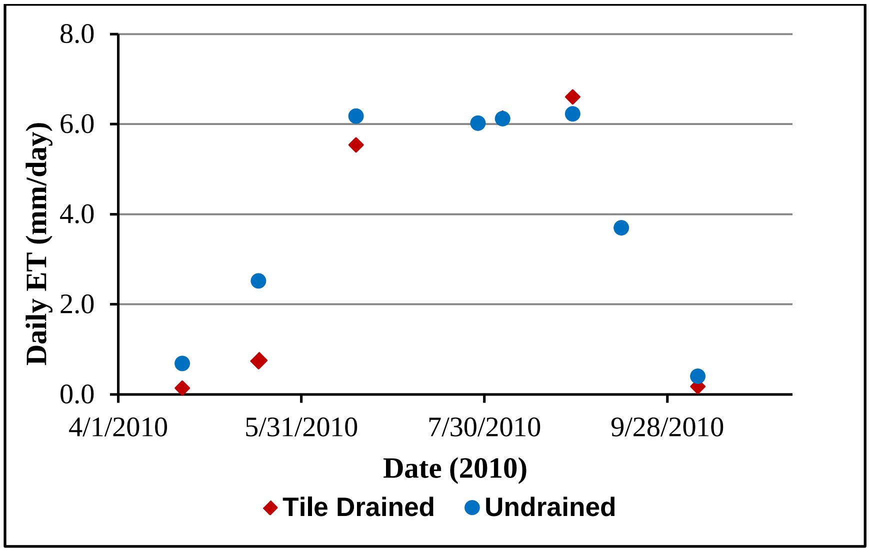


Figure 2. Daily soybean ET values from drained and undrained areas for selected satellite image dates for year 2010.

Site 2: Tracy, MN

There were fewer cloud-free image dates available for the 2008 growing season at the Tracy, MN site. For the available image dates, there was less than 1 mm/day difference in soybean ET between the drained and undrained fields except for the May 20 image date when there was a 2.2 mm/day difference (Figure 3). This resulted in 25% greater ET from the undrained field (539 mm) than from the drained field (432 mm) for the growing season, which was statistically significant. However, heavy insect pressure on the drained field, which resulted in yield loss, was confounded with the drainage and may explain more of the ET difference.

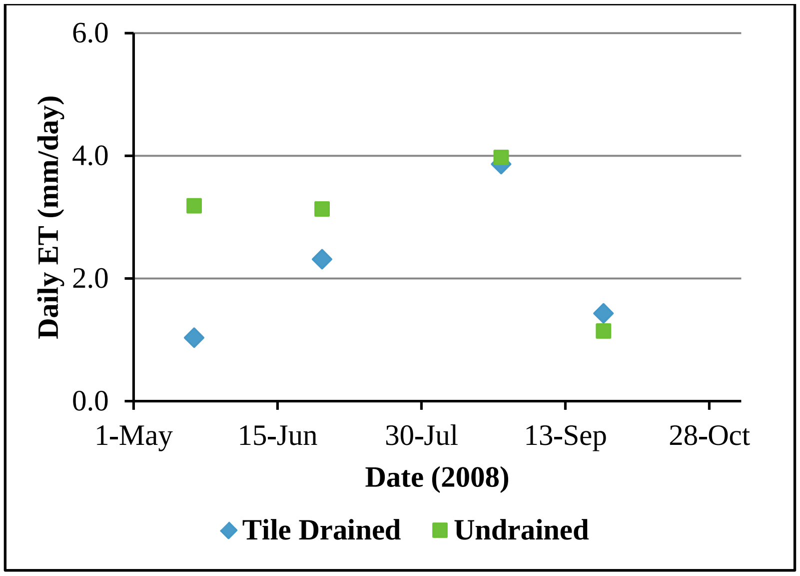


Figure 3. Daily soybean ET rates from drained and undrained fields for selected satellite image dates for year 2008.

Site 3: Lennox, SD

Differences in corn ET between the drained and undrained areas were less than 1 mm/day for all the image dates at the Lennox site in 2013 (Figure 4). The overall difference in ET for the growing season was only 1 mm between the undrained (684 mm) and drained areas (683 mm). This difference was not statistically significant.

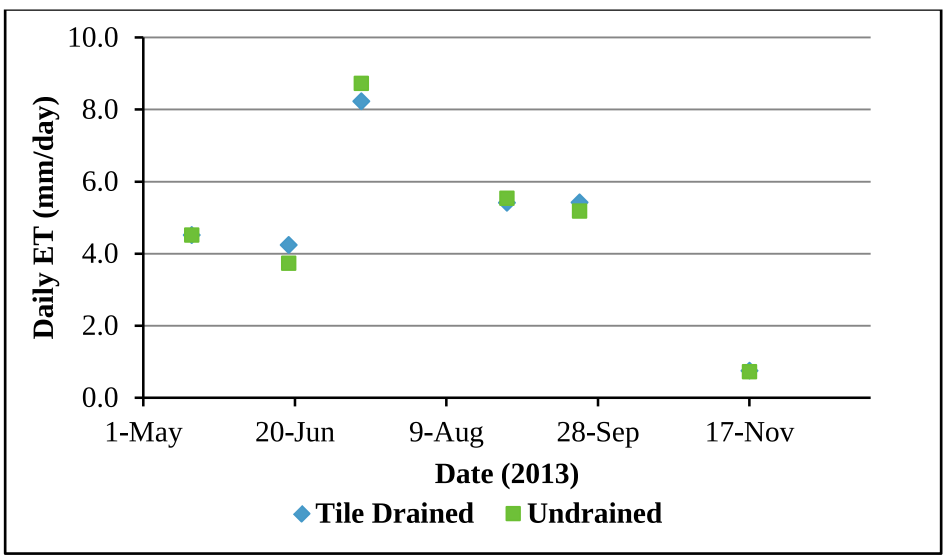


Figure 4. Daily corn ET estimates from drained and undrained areas for selected satellite image dates for year 2013.

Education and Training

One masters student was trained as part of the project. The project funds covered his graduate assistantship, and the research was the basis of his thesis. The student was trained in evapotranspiration, drainage, meteorological data quality control, remote sensing, and the METRIC model.

Products

Conference Proceedings Papers

1. Khand, K., J. Kjaersgaard, C. Hay, and X. Jia. 2014. Estimating evapotranspiration from drained and undrained agricultural fields using remote sensing. ASABE Paper No. 1829687. St. Joseph, Mich.: ASABE. [Oral Presentation—Khand]
2. Kjaersgaard, J., K. Khand, C. Hay, and X. Jia. 2014. Estimating evapotranspiration from fields with and without tile drainage using remote sensing. World Environmental and Water Resources Congress 2014: pp. 1745–1753. doi: 10.1061/9780784413548.173. [Oral Presentation—Kjaersgaard]

Presentations

1. Khand, K., J. Kjaersgaard, and C. Hay. 2014. Evaluating impacts of subsurface drainage on evapotranspiration using remote sensing. 15th Annual Iowa-Minnesota-South Dakota Drainage Research Forum, Ames, Iowa. 18 Nov. [Invited presentation—Hay]
2. Kjaersgaard, J., K. Khand, and C. Hay. 2014. Estimating impacts of tile drainage on crop consumptive water use. Western South Dakota Hydrology Conference, Rapid City, S.D. 9 April. [Oral presentation—Kjaersgaard]
3. Khand, K.B., C. Hay, J. Kjaersgaard, and T. Trooien. 2013. Subsurface drainage impacts on evapotranspiration (ET). Eastern South Dakota Water Conference, Brookings, S.D. 30 Oct. [Poster presentation—Khand]

Changes/Problems

The drought in 2012 and less than expected drain flow in 2013 resulted in insufficient data with which to develop enough DRAINMOD simulations for the original project objectives. Therefore, a different approach was developed using a remote sensing approach to compare ET from drained and undrained fields. The new approach remained within the overall project goal, but resulted in a new set of objectives.

Evaluation of wastewater produced in biomass pyrolysis process

Basic Information

Title:	Evaluation of wastewater produced in biomass pyrolysis process
Project Number:	2012SD216B
Start Date:	3/1/2012
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	First
Research Category:	Engineering
Focus Category:	Acid Deposition, Water Use, Treatment
Descriptors:	
Principal Investigators:	Lin Wei, Todd P. Trooien

Publications

1. Liu, Z., L. Wei, J. Julson, Y. Huang, Y. Gao, X. Zhao, Characterization of bio-oil aqueous phase for recovery of organic acids. Poster, 2014 ASABE/CSAE Intersectional Meeting, Brookings, SD 57007
2. Liu, Z., L. Wei, J. Julson, Y. Huang, Y. Gao, X. Zhao, Evaluation of wastewater produced in biomass pyrolysis process, 2013 ASABE Annual International Meeting, Kansas city, MO 64101
3. Liu, Z., L. Wei, J. Julson, Y. Huang, Y. Gao, X. Zhao, Evaluation of wastewater produced in biomass pyrolysis process, journal of biomass and bioenergy, plan to submit in Oct. 2014
4. Evaluation of wastewater produced in biomass pyrolysis process, full paper to be presented in 2014, ASABE/CSAE Annual International Meeting, Montreal, Quebec, Canada
5. Liu, Z., L. Wei, J. Julson, Y. Huang, Y. Gao, X. Zhao, Characterization of bio-oil aqueous phase for recovery of organic acids. Poster, 2014 ASABE/CSAE Intersectional Meeting, Brookings, SD 57007
6. Liu, Z., L. Wei, J. Julson, Y. Huang, Y. Gao, X. Zhao, Evaluation of wastewater produced in biomass pyrolysis process, 2013 ASABE Annual International Meeting, Kansas city, MO 64101
7. Liu, Z., L. Wei, J. Julson, Y. Huang, Y. Gao, X. Zhao, Evaluation of wastewater produced in biomass pyrolysis process, journal of biomass and bioenergy, plan to submit in Oct. 2014
8. Evaluation of wastewater produced in biomass pyrolysis process, full paper to be presented in 2014, ASABE/CSAE Annual International Meeting, Montreal, Quebec, Canada
9. Liu, Z., L. Wei, Y. Huang, Todd Trooien, investigation of wastewater produced from corn stover and sawdust pyrolysis, ASABE/CSAE Intersectional annual meeting, 2014, July 17 - 21, Montreal, Canada.
10. Huang, Y., L. Wei, J. Julson, 2014. Upgrading of bio-oil into advanced bio-fuel over Mo/H-ZSM5 catalysts. The ASABE/CSBE North-Central Intersectional Meeting, March 28-29, Brookings, SD.

Project Final Report

Project Title: Evaluation of wastewater produced in biomass pyrolysis process

Project Director/Principal Investigator:

Dr. Lin Wei, assistant professor, Department of Ag. & Bio. System Engineering, South Dakota State University, Brookings, SD 57007

All Co-Principal/Other Investigators:

Dr. Todd Trooien, Professor, Department of Ag. & Bio. System Engineering, South Dakota State University, Brookings, SD 57007

Collaborators (Cost-Sharing Partners): N/A
Project Location*:*

South Dakota State University, Brookings, SD 57007

Project Start Date: 03/01/2012

Project End Date: 08/30/2014

Date of Final Report: 05/10/2015

Reporting Period: March 1st, 2012 to August 30th, 2014
Date of Report: May 10th, 2015
Written By: Dr. Lin Wei, Dr. Todd Trooien

Executive summary
The major accomplishments completed in this project include:

- Corn stover and sawdust were converted to crude bio-oil using fast pyrolysis process. After storage in containers for two more weeks, the produced crude bio-oil separated into two phases, an oil phase and an aqueous phase (wastewater), due to re-polymerization and oxidation reactions. The oil phase of crude bio-oil was upgraded to a drop-in fuel using a catalytic cracking process. The wastewater was diluted and then divided to colorless wastewater and lipophilic wastewater using a Sep-Pak SPE column. The colorless wastewater samples were analyzed for determinations of organic acids using HPLC and GC-MS. The lipophilic wastewater was analyzed for identification of functional groups in the wastewater using NMR.
- The oil phase of crude bio-oils was upgraded to a new liquid product that consists of two phases: drop-in fuel and new wastewater. Heavy metal Mo catalysts were used in the bio-oil catalytic cracking process. The drop-in fuel was sent to another ongoing project for further analysis. Similarly, the wastewater was diluted and then divided to colorless wastewater and lipophilic wastewater using a Sep-Pak SPE column. The colorless wastewater samples were analyzed for determinations of organic acids using HPLC and GC-MS. The lipophilic wastewater was analyzed using NMR. The organic component profiles are different between the wastewater samples produced from bio-oil upgrading and crude bio-oil.
- We collected and characterized the wastewater including pH value, dissolved oxygen (DO), and salinity such as electrical conductivity (EC). The results of GC/MS analysis indicate

that there were still some water soluble organic compounds/hydrocarbons left in the wastewater. There may be still potential for harnessing value-added products from the wastewater if properly treated.

- We measured the heavy metal (Mo) residues in the wastewater produced from bio-oils upgrading. There was 6.18 PPM (mg/kg) of Mo residues in the wastewater sample when 9% of Mo combined with HZSM-5 was used as catalyst in the bio-oil upgrading process.
- We suggested that the wastewater should be properly treated before release to environment.
- One paper and two presentations were given at the 2014 ASABE conferences.
- Seven PhD/M.S. graduate students (Including Yijing Wang, Parvathi Jampani, Dan Liu, Zhongwei Liu, Xianhui Zhao, Yinbin Huang, and Wangda Qu) and two postdocs (Chunkai Shi and Yang Gao) participated in the project. They were trained to carry out the experiment of biomass pyrolysis conversion and wastewater analysis.

Background

Because of world population explosion and rapidly growing economy, food, water, and energy are the most urgent challenges need to be addressed today. Currently biomass is known as the only source for production of renewable liquid transportation fuels. Pyrolysis is a very promising process to effectively convert biomass materials such as corn stover, switchgrass, wood residues, etc. to liquid transportation fuels. Properly utilizing biomass may have important positive impacts on national energy security, local economic growth, and environmental protection. However, biomass pyrolysis also produce wastewater during biofuel production, as much as 20 – 50% of the volume of biofuel produced, depending on the biomass pyrolysis and bio-oil upgrading technologies used. This wastewater may have various contaminants and a high chemical oxygen demand (COD) level, which would cause severe pollution if released into the environment without treatment. The contaminants make the wastewater unusable for some purposes. Even after processing for extra value-added products, many of these compounds may still left behind and resist biological degradation or exert significant toxicity towards environments. But the wastewater may be usable for other purposes or treatments may be available to make the wastewater usable for still other purposes. The goal of this research is to evaluate the wastewater produced during catalytic pyrolysis of biomass feedstocks and upgrading the bio-oil to drop-in fuel. In addition, the wastewater produced from vegetable oil upgrading to drop-in fuel was also examined. The specific objectives of the research are:

1) Conduct catalytic fast pyrolysis process for converting various biomass feedstocks into liquid drop-in biofuels.
2) Characterization of the wastewater produced
3) Explore possible solutions for wastewater utilization.

Planned activities:

Table 1 planned tasks to be completed in this study

Task 1	Set up pyrolysis reactors and prepare biomass feedstocks including corn stover and wood sawdust.
Task 2	Conduct pyrolysis tests for converting the feedstocks into bio-oil. Evaluate the bio-oil and collect the wastewater generated for evaluation.

Task 3	Upgrade the bio-oil to drop-in fuels. Evaluate the drop-in fuels and collect the wastewater generated for analysis.
Task 4	Characterize the wastewater generated from fast pyrolysis and evaluate its potential
Task 5	Characterize the wastewater produced from bio-oil upgrading and evaluate its potential
Task 6	Based on the results of characterization and analysis of the wastewater, the study will provide suggestions for renewable energy industries, biomass producers, and/or lawmakers and the research team will search more external funds for further research.

We completed all the tasks planed on 08/30/2014. The work we have done is reported here.

Actual Accomplishments:

<u>Task 1. Set up pyrolysis reactor systems and prepared feedstock</u>

A liquid biofuels production system including a catalytic fast pyrolysis (CFP) reactor and a bio-oil upgrading HDO reactor was set up in the Advanced Biofuel Development Laboratory (ABDL) in the Ag. and Bio. System Dept. on SDSU campus.This system can convert various biomass materialsto bio-oil and then upgrade the bio-oil into liquid biofuels (mixed hydrocarbons) that are compatible to petroleum hydrocarbons and can be directly dropped into existing petroleum refinery for production of “green” gasoline, diesel, and jet fuels. This liquid biofuel is so called “drop-in fuel”. The corn stover obtained from a corn farm at Brookings, SD 57006, and the pine wood shavings bought from a lumber company, Hills Products Group at Spearfish SD 57783, were used as feedstocks in this study. These feedstocks were first air-dried and then ground into powder. The moisture content and particle size of the powders were determined and the results are showed in Table 2. Analysis of particle size distribution is shown as Figure 1 and 2 respectively.

Table 2 Moisture Content of Feedstock

Feedstock	Corn Stover	Pine Sawdust
Moisture Content (wt %)	6.05	7.15
Particle Size < 1mm (wt %)	87	85

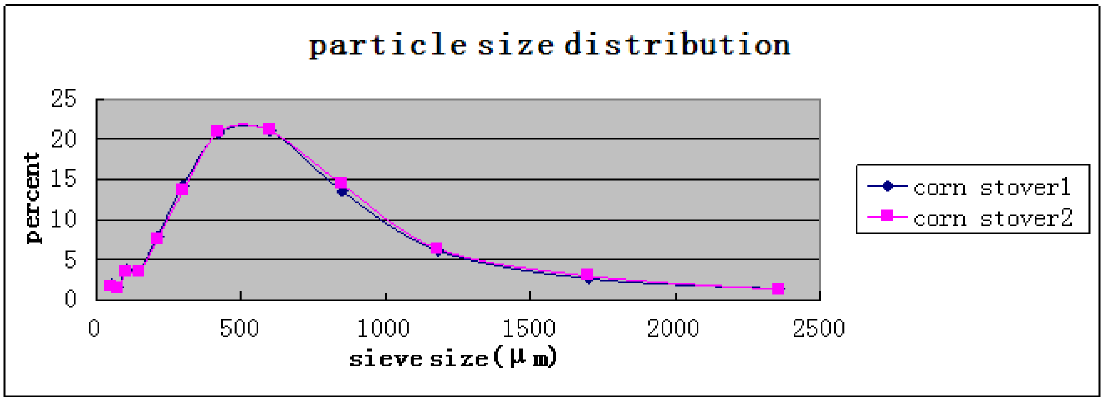


Figure 1 Particle size distribution of the corn stover powder

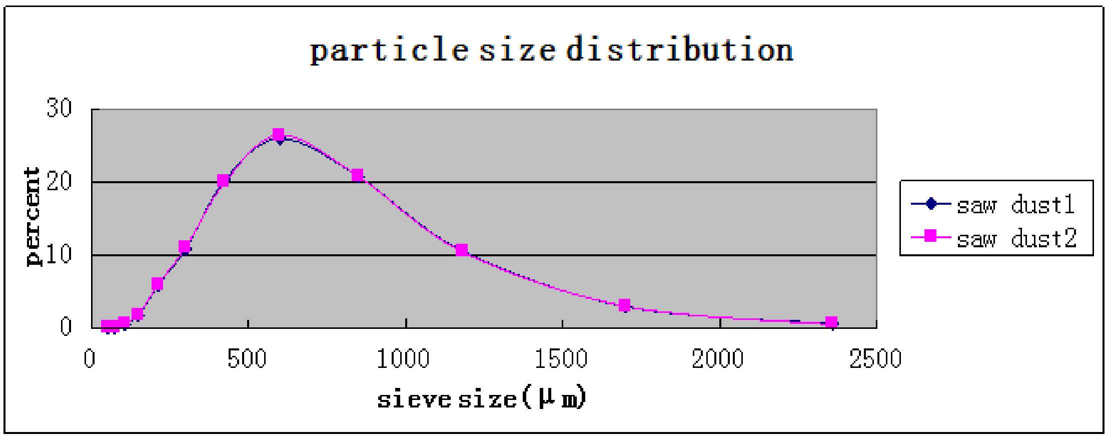


Figure 2 Particle size distribution of the pine sawdust

<u>Task 2. Conduct biomass pyrolysis and bio-oil upgrading tests</u>

The prepared biomass feedstocks were fed into the CFP reactor to produce bio-oils at three different temperatures (537°C/1000°F, 648°C/1200°F, and 760°C/1400°F) respectively. 2 kg/h of biomass feedstock feeding rate was used for each test. After each test run, bio-oil samples were immediately characterized. Bio-oil density, pH value, dynamic viscosity, heating value, water content, organic elemental content, etc. were determined. The chemical composition of bio-oil was also analyzed by using a Gas chromatography/mass spectrometry (GC/MS) system (Agilent model 5890 with DB-5 column). The yield rate of bio-oil and wastewater produced were also calculated. Up to 65% of bio-oil yield from sawdust has been achieved. The characterization results are showed in Table 3.The bio-oils' chemical composition profiles are shown as Figure 3. The compounds having high peaks in the profiles were identified by an internal data library (NIST08).

Table 3   Properties of bio-oil produced

Properties	Corn Stover	Pine Sawdust

Density (g/ml)	1.048	1.045
pH	2.7- 3.5	2.0-2.9
Viscosity (cp at 20°C)	3.2	9.8
Moisture Content (wt%)	54.88	47.04
Heating Value (MJ/Kg)	10.19	13.81

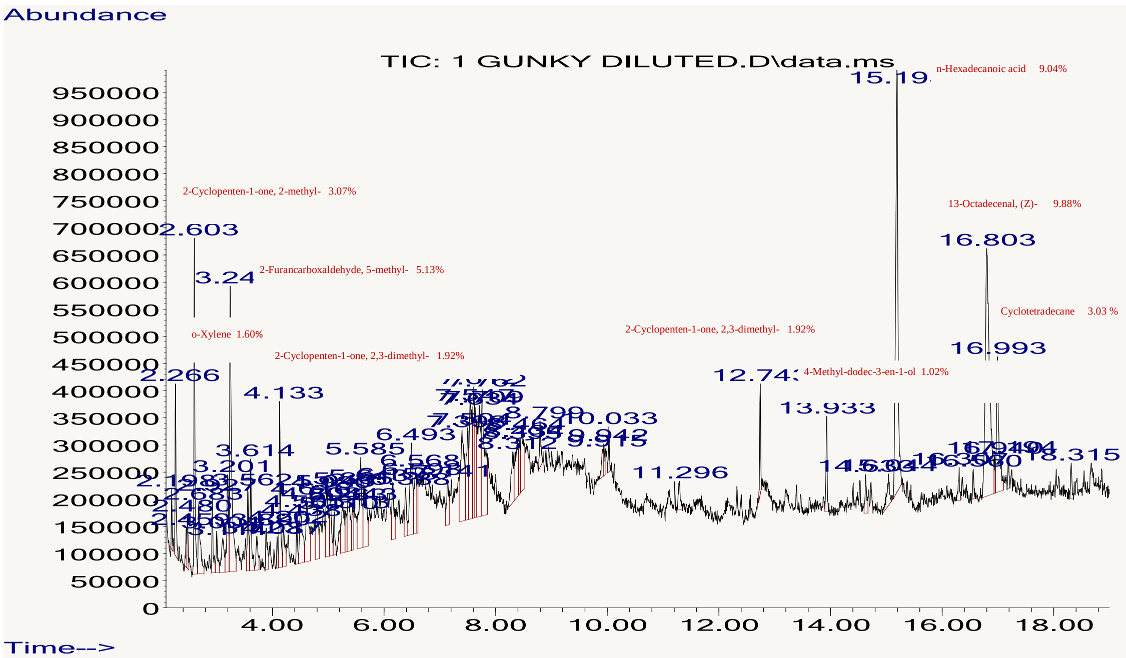


Figure 2. GCMS analysis of raw bio-oil

The bio-oils produced from corn stover and sawdust were fed into the bio-oil upgrading HDO reactor to be converted into liquid bio-fuels (mixed hydrocarbons). Zeolite based and activated carbon based catalysts were prepared and used in the bio-oil upgrading process. After bio-oil upgrading, good quality drop-in fuel was obtained. The drop-in fuels' properties are shown in the table 4. The results indicated that the liquid mixed hydrocarbons are compatible to petroleum-based hydrocarbons and very close to gasoline and diesel. They can be compatible to petroleum hydrocarbons and can be dropped into existing petroleum refinery.

Table 4 Comparison of raw bio-oil and upgraded bio-oil, produced from corn stover, and petroleum based gasoline, diesel and jet fuel

Properties	**SDSU Raw bio-oil**	**SDSU Upgraded bio-oil**	**Gasoline**
pH value	2.8 – 3.2	5.0 – 5.6	N/A
Viscosity cSt @20°C	20 – 50	1.2 – 1.88	0.4 – 0.8
Density, Kg/L	0.9 – 1.06	0.8 – 0.85	0.745

Heating value, MJ/kg	16 – 23	41 – 45	43
Carbon content, % w.t.	24 – 28	84.59 – 85.12	85 – 88
Hydrogen content, % w.t.	8.5 – 10.1	10.9 – 11.26	12 – 15
Oxygen content, % w.t.	35 – 40	1.4 – 1.72	0
Water content, % w.t.	35 – 47	< 0.2%	0

Task 3. Collection and characterization wastewater samples produced from biomass pyrolysis

After bio-oil upgrading, the volume of wastewater produced was 40 to 50% of the bio-oil volume. The wastewater samples produced in different biomass pyrolysis tests were collected and characterized. The wastewater pH value, dissolved oxygen (DO), and salinity, measured as electrical conductivity (EC) were measured with portable probes. The test results are shown in table 5. GC/MS analysis was also carried out for the wastewater sample produced from sawdust pyrolysis (Figure 5).

Table 5 Properties of the wastewater produced from different biomass pyrolysis tests

Wastewater sources	pH	DO, Mg/L	EC, uS/cm	Salinity hazard rating for irrigation
Sawdust	3.6	5.5	380	Medium
Sawdust	3.3	6.6	810	High
Corn stover	3.1	5.8	660	Medium
Corn stover	2.4	6.8	670	Medium
Prairie grass	2.7	6.5	620	Medium

The five samples with EC values of less than 750 uS/cm would be considered medium salinity hazards for use as irrigation water. Values greater than 750 uS/cm would result in salinity hazard ranking in the low end of the High hazard ranking. Assuming any irrigated soils would have reasonable permeability and allow at least some drainage and salt leaching, the salinity risks posed by these wastewater samples are less than many irrigation water sources used in the region. The results of GC/MS analysis indicate that there were still some water solvable organic compounds/hydrocarbons left in the wastewater. There may be still potential for harnessing value-added products from the wastewater if properly treated.

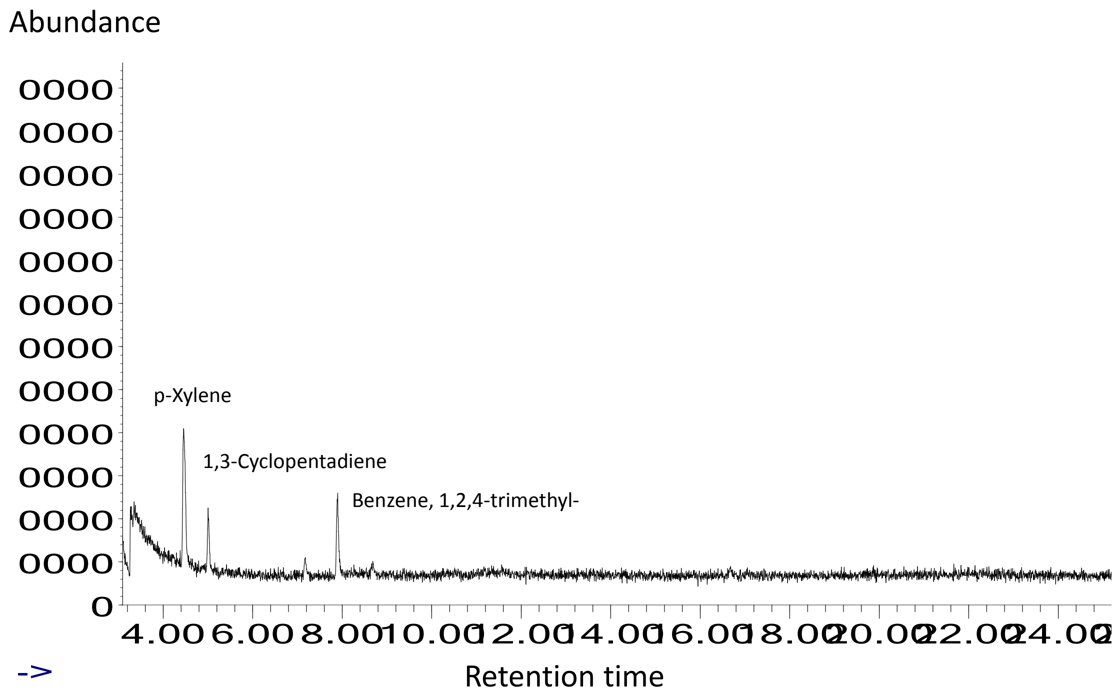


Figure 3 GCMS analysis of wastewater produced from bio-oil upgrading,

Task 4. Upgrade crude bio-oils to drop-in fuel using a bench scale fixed-bed reactor

Two new bench scale tubular fixed-bed reactors were assembled and used for the bio-oil and vegetable oil upgrading experiment. Heavy metal Molybdenum (Mo) and HZSM-5 were used to prepare catalysts applying in the upgrading processing. The schematic diagram of the reactors is shown in Figure 4. This system consists of a pre-heater (furnace 1), a catalytic cracking fixed-bed reactor (furnace 2) and a condenser unit. When the test starts, nitrogen is used to purge the air inside the system for about 10 minutes. The furnace 1 preheats and vapors the raw bio-oil/vegetable oil. This oil vapor enters the fixed-bed reactor where the furnace 2 heated to reaction temperatures. The actual catalytic cracking reactions take place in the reactor. The products of these reactions are condensed to liquid consisting primarily of a mixture of water phase and oil phase. The non-condensable gases called syngas exits the condenser and is delivered to storage. The oil phase samples are collected and sent to another ongoing project to analyze their chemical composition and physicochemical properties. Typical GC-MS profiles of the oil phase chemical compositions of crude sawdust bio-oil and the upgraded bio-oil are shown in Figure 5 and 6. The water phase (so called wastewater in this project) samples are also collected and analyzed in this report.

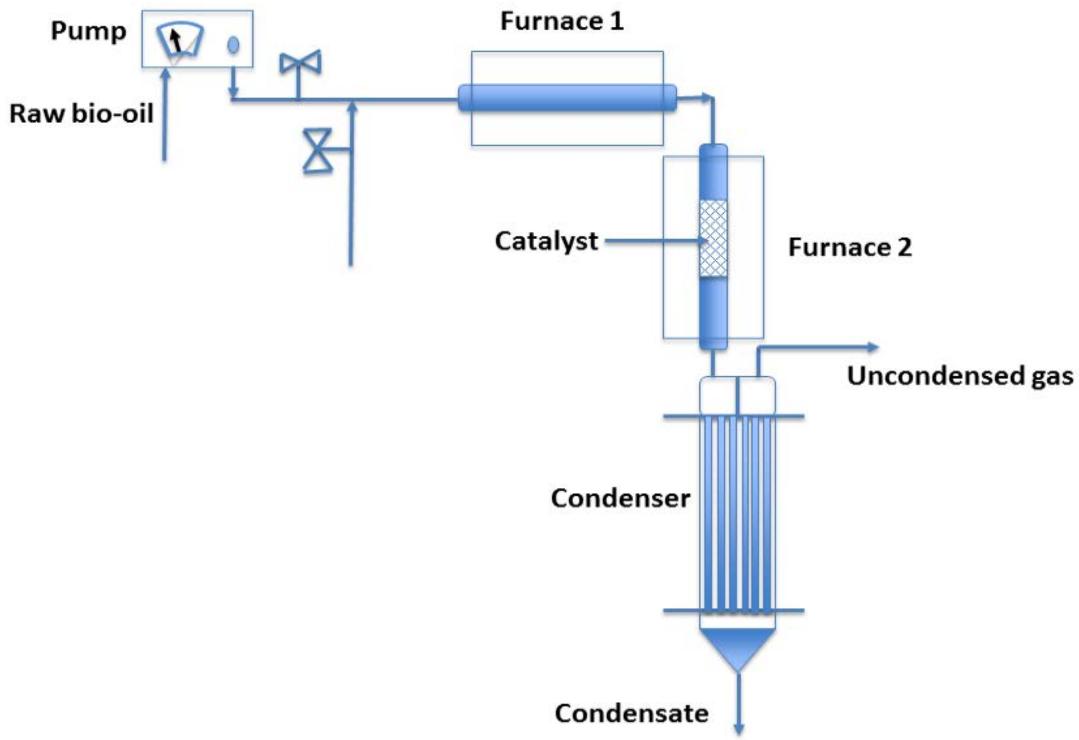


Figure 4. The schematic diagram of the experiment system

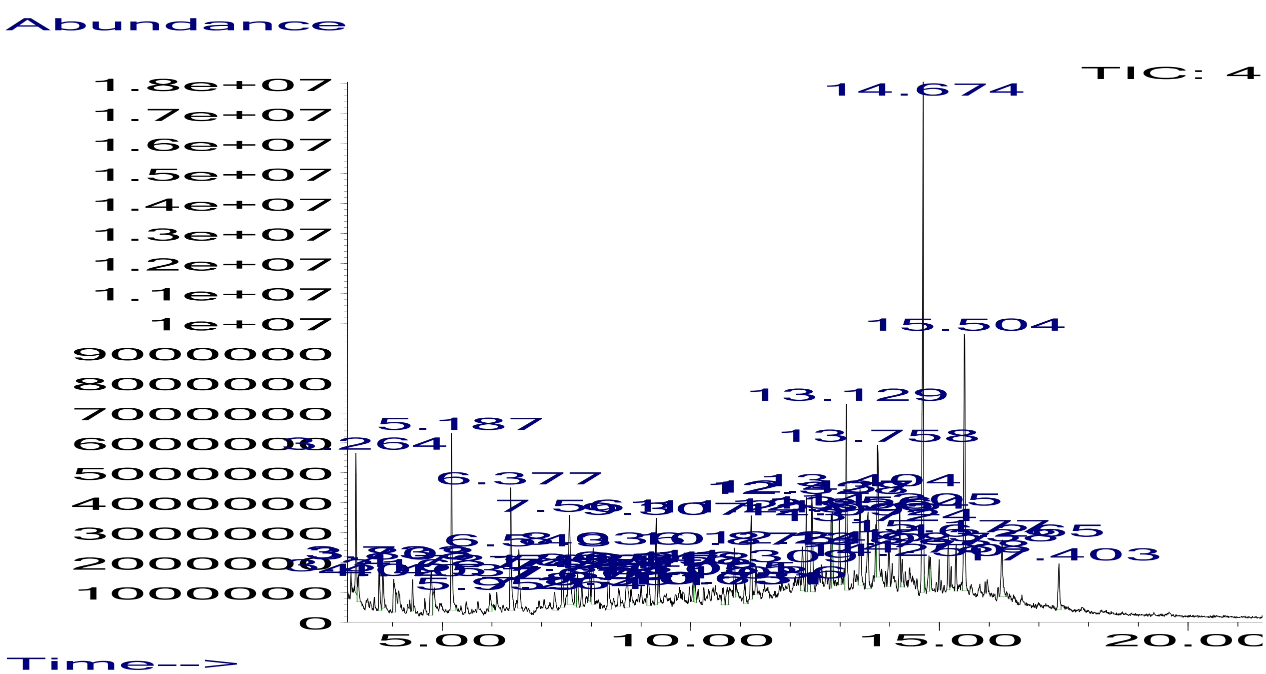


Figure 5. GC/MS profile of crude sawdust bio-oil

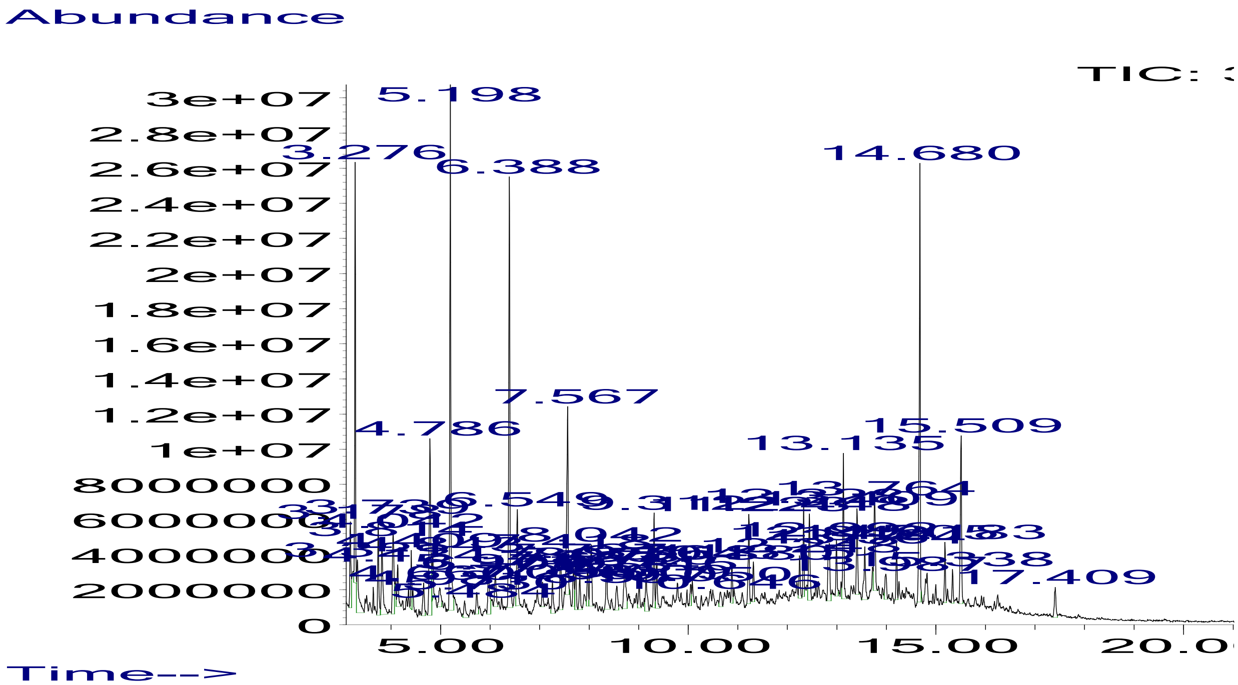


Figure 6. A GCMS profile of upgraded sawdust bio-oil

<u>Task 5. Characterization of wastewater samples from bio-oil upgrading</u>

The wastewater samples collected from sawdust pyrolysis were characterized by using the following protocols.

1) Wastewater sample of raw sawdust bio-oil was diluted 20 times.
2) The diluted samples were applied to Sep-Pak SPE column to remove lipophilic components that will be analyzed by NMR
3) The purified samples were analyzed by HPLC using an Aminex HPX-87H Column, and thus compared to individual organic acid standards for qualitative and quantitative analysis of the samples.

The HPLC profile of the wastewater sample produced from crude sawdust bio-oil is showed as Figure 7. Compared with organic acid standards, four peaks in the profile were identified. They are acetic acid (46.8 mg/ml), formic acid (13.68 mg/ml), butanoic acid (4.5 mg/ml), and propionic acid (3.7 mg/ml). The other two peaks were unable to be identified in this HPLC analysis, but will be identified by later GC-MS analysis.

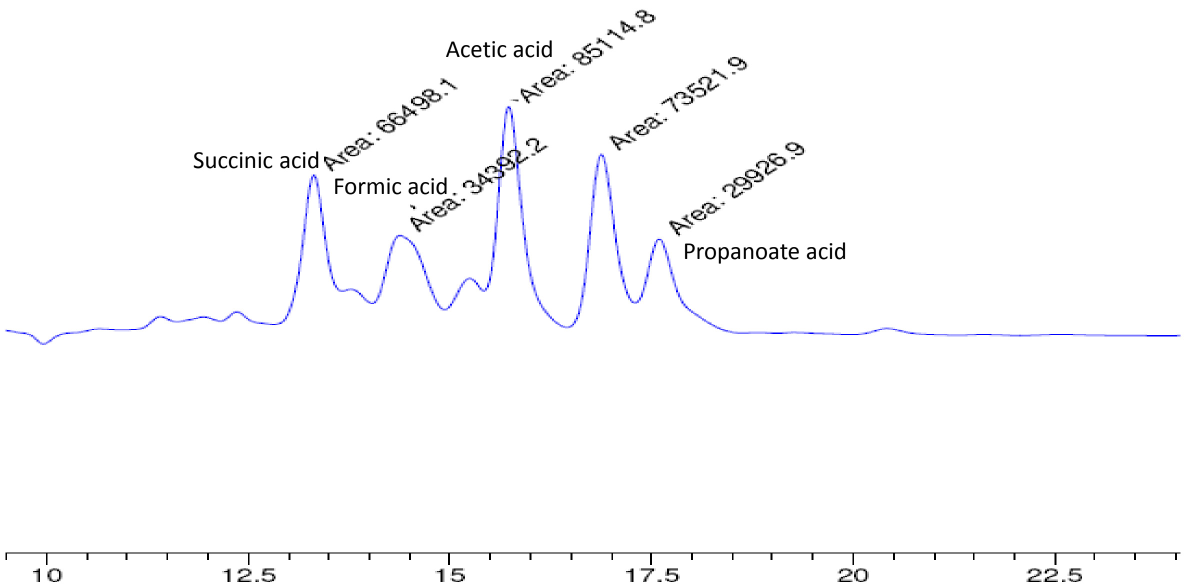


Figure 7. The HPLC profile of wastewater sample from crude sawdust bio-oil

The HPLC profile of organic acid in the wastewater samples produced from sawdust bio-oil upgrading is shown in Figure 8. Compared with the wastewater samples from crude bio-oil, the succinic acid (2.5 mg/ml), formic acid (6mg/ml), and acetic acid (10.2 mg/ml) concentrations have significantly decreased. Again, the peak at retention time of 19 minute will be identified by later GC-MS analysis.

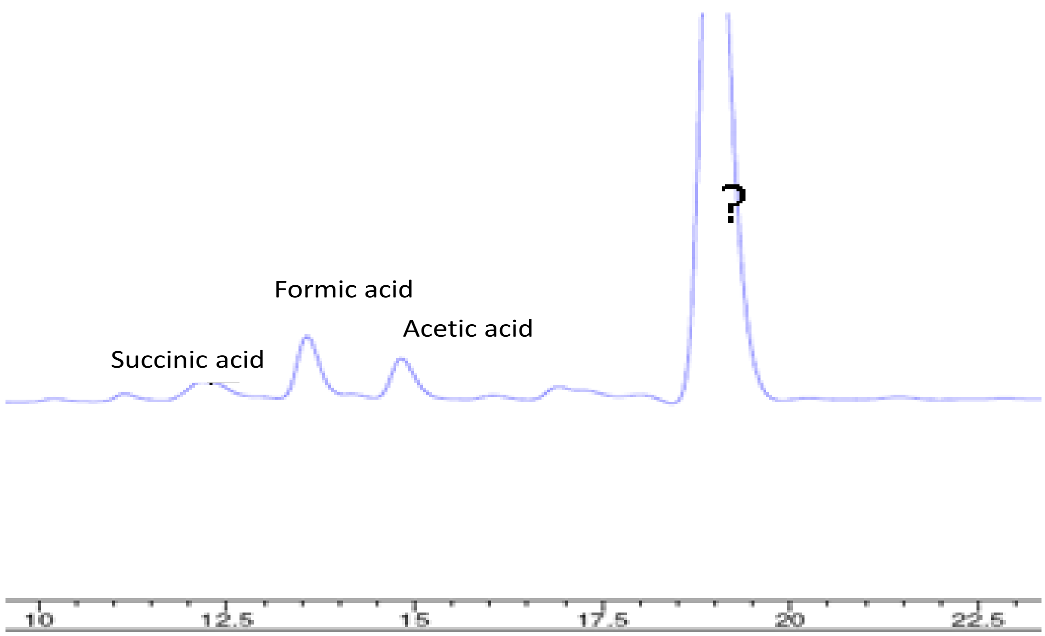


Figure 8 the HPLC profile of organic acids in the wastewater produced from sawdust bio-oil upgrading.

Similarly, the wastewater samples collected from vegetable oil (sunflower oil) upgrading to drop-in fuels were also characterized by using HPLC analysis. The HPLC profile of the wastewater is shown in Figure 9. Compared with organic acid standards, two peaks in the profile were identified. They are acetic acid (74.52 mg/ml), succinic Acid (1.69 mg/ml), and propionic acid (5.55 mg/ml). The other two peaks were unable to be identified in this HPLC analysis, but will be identified by another GC-MS analysis conducted in next quarter.

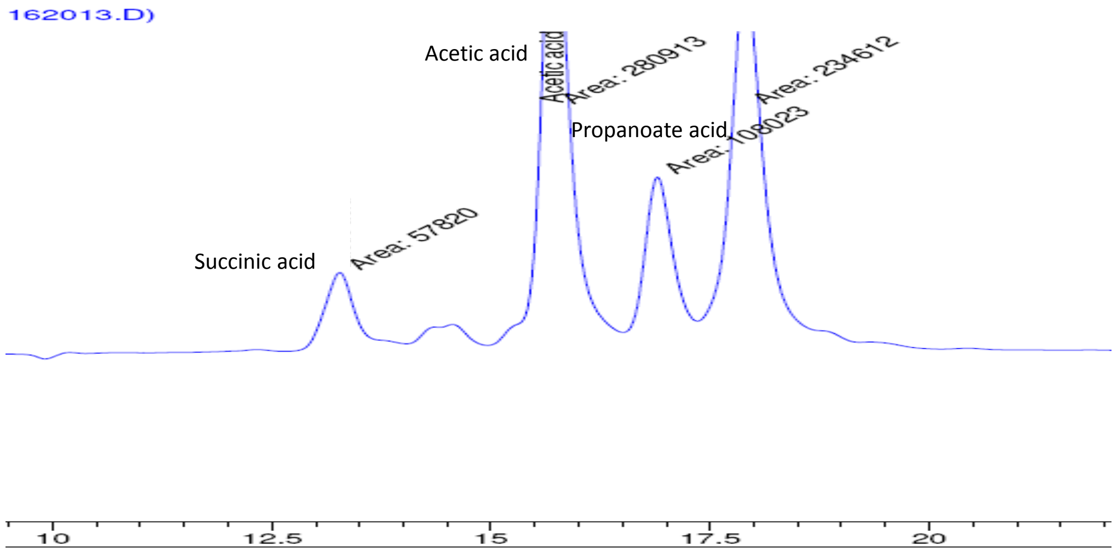


Figure 9. A HPLC profile of wastewater sample from sunflower oil upgrading to drop-in fuel

GC-MS analyses of organic acids in wastewater samples produced from crude sawdust bio-oil and the bio-oil upgrading were carried out. In addition, GC-MS analyses of organic acids in wastewater samples produced from sunflower oil upgrading process was also conducted in this study since non-food vegetable oil (sunflower oil) may be one of important sources for biofuel productions. After Sep-Pak SPE extraction, the bio-oil wastewater was divided into colorless portion which was passed through the SPE column directly, and dark-brown portion which was retained on the SPE column and eluted out by methanol. GC-MS analyses of the colorless portions were performed by following the method described below:

1) 1 μL of sample was injected in a split mode (7:1) into the GC-MS system (Agilent 6890 with an Agilent 5973 mass selective detector and Agilent 7683B auto sampler).
2) Gas chromatography was performed on a 15 m ZB-FFAP column with 0.25 mm inner diameter (I.D.) and 0.25 μm film thickness (Phenomenex, Torrance, CA, USA) with an injection temperature of 200℃, MSD transfer line of 250℃, and the ion source adjusted to 230℃. The helium carrier gas was set at a constant flow rate of 1.6 ml min^{-1}. The temperature program was isothermal 105℃ for 6 min. The mass spectrometer was operated in positive electron impact mode (EI) at 69.9 eV ionization energy in m/z 33-150 scan range.
3) The spectra of all chromatogram peaks were evaluated using the HP Chemstation (Agilent, Palo Alto, CA, USA). The spectra of all chromatogram peaks were compared with EI mass spectra obtained for authentic standards. Calibration curves were built for the concentration range 0.1-1g/L.

The GC-MS analysis results are shown in Figure 10 and 11. Since the wastewater samples for GC-MS analyses had been diluted 20 times, a proportional method was used to calculate the actual acetate and propanoate concentrations (Figure 12). The calculations are listed in table 6. The actual acetate concentrations were 1.242 M and 0.782 M while propanoate concentrations were 74 mM and 46 mM in the wastewater samples produced from sunflower oil and crude bio-oil, respectively.

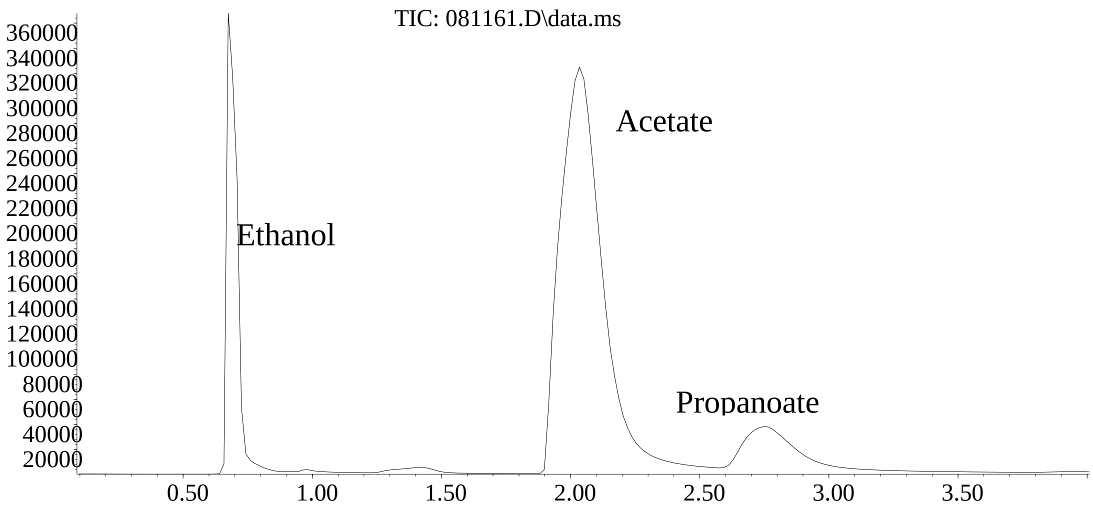


Figure 10 GC-MS profile of wastewater produced from vegetable oil upgrading to drop-in fuel

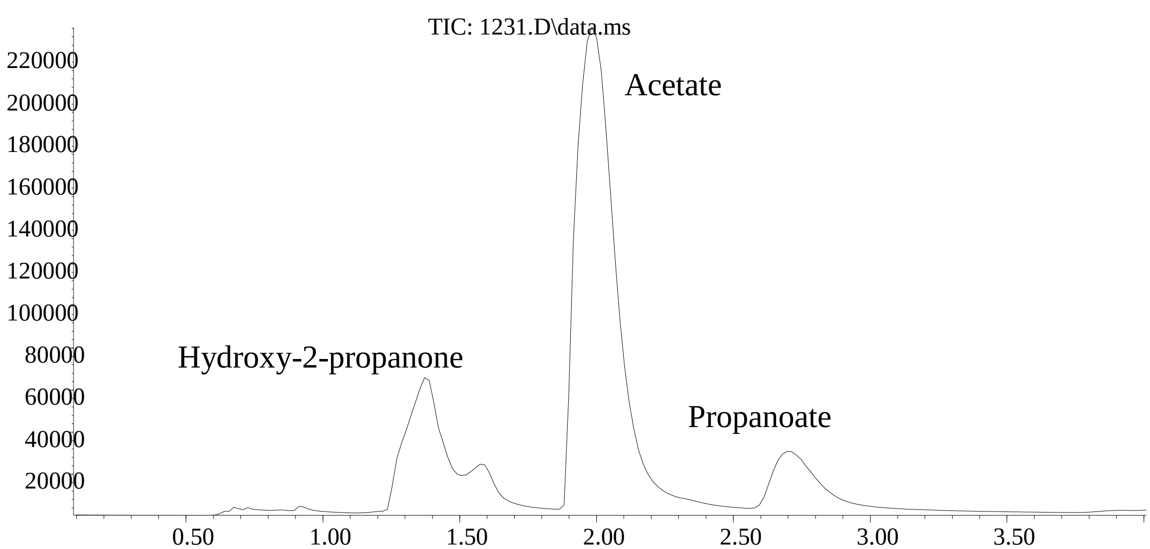


Figure 11 GC-MS profile of wastewater produced from crude sawdust bio-oil

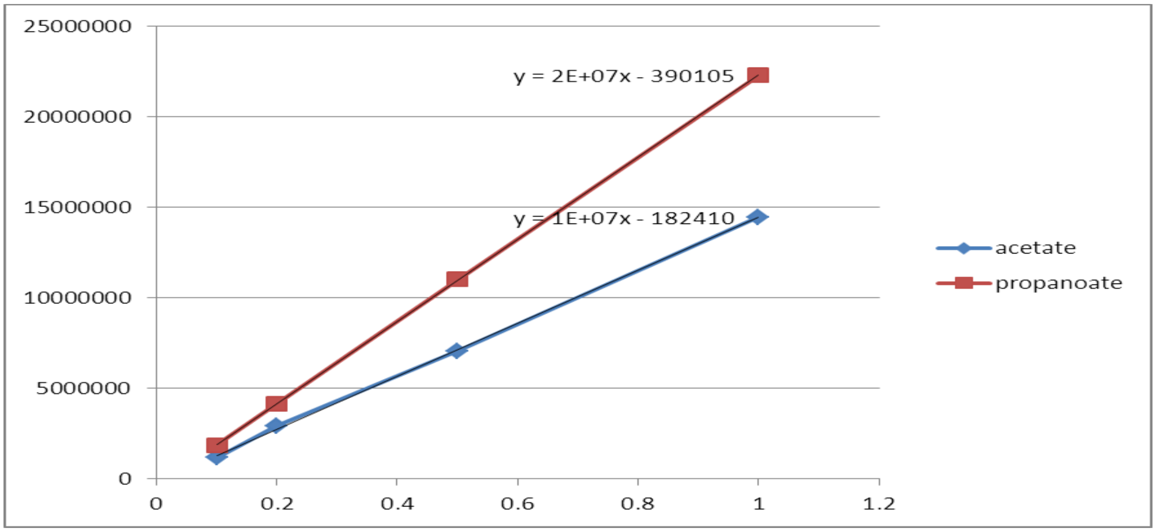


Figure 12 Calculation of organic acid concentration in the wastewater samples what are the values and units on the X and Y axes?

Table 6 Acetate and propanoate concentrations in the wastewater samples

sample data	Vegetable oil wastewater **(mM)**	Bio-oil wastewater **(mM)**
acetate	62.1	39.1
propanoate	3.7	2.3

NMR analyses were used to examine function groups of the methanol elute colorful ??? portions of the wastewater produced from sawdust bio-oil. The chemical shifts 6.5-7 ppm in the ^{1}H spectrum (Figure 13) of the methanol elute portion clearly indicated the presence of lignin pyrolysis phenolics which also contribute to the dark brown color of the wastewater. The hydrogen percentage of aromatic region (6.5-7 ppm) is about 35% while there are no significant peaks in the carbohydrate region (4-5.5 ppm). This result is consistent with our previous result and revealed that there are no monosaccharides in the wastewater of the crude sawdust bio-oil.

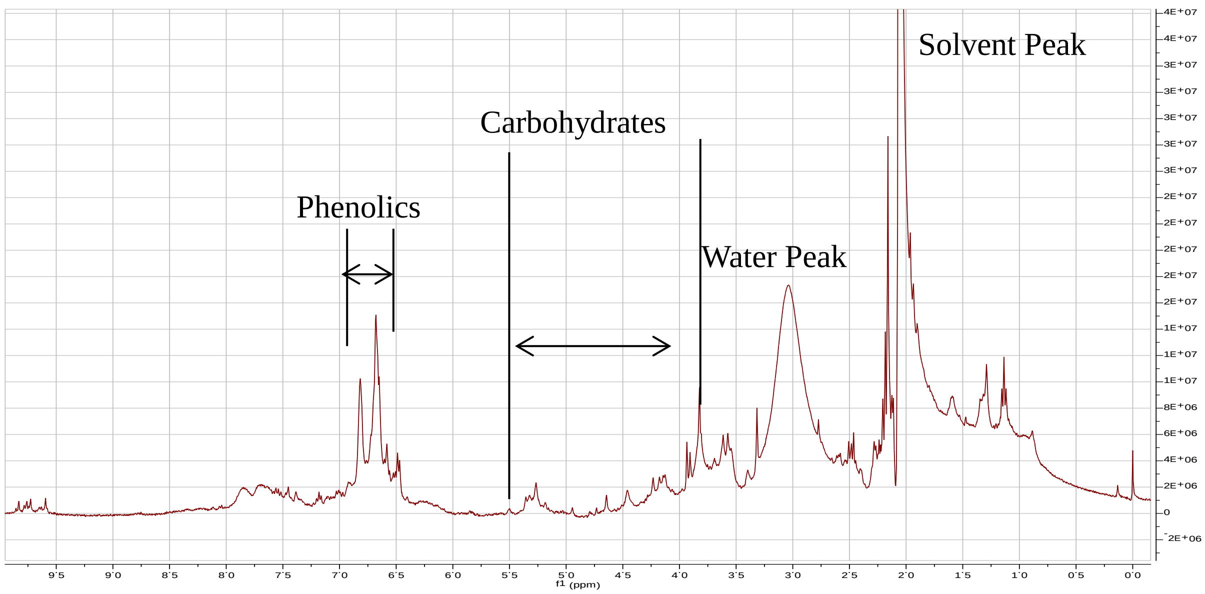


Figure 13 The NMR ^{1}H spectrum of wastewater samples produced from crude sawdust bio-oil

Since heavy metal Molybdenum (Mo) was used as catalyst for upgrading bio-oil, the presence of Mo in the produced wastewater should be detected. By using ICP-OES, the determination of heavy metal (Mo) remaining in the wastewater samples was carried out by the laboratory, Analytical Consulting Services, Inc. Houston TX 77084. The sample preparation protocols and instrument operations are briefly described as below:

The steps of preparing wastewater sample

- Microwave digestion was performed using a state of the art CEM (MARS 6) closed vessel technology.
- 0.5 g of sample was digested in duplicate with matrix blanks by use of microwave.
- Samples were poured up to a known volume and sent to the analytic labs for analysis using ICP-OES.

Operations of the Thermo 6500 ICP-OES

- Calibration standards are matrix matched to perform 3 point curve, 0, .1, 1.0 ppm.
- Samples are diluted and run against the calibration curve.
- Matrix blanks, sample blanks, and spike samples are run as well as the wastewater samples.
- Known results are calculated by known weight and volume. Results given are reported in PPM values.
- Detection limits of known samples are 10ppb and higher.

The result is shown as Figure 14. It was found that the concentration of Mo was 6.18 PPM (mg/kg) in the wastewater sample produced from sawdust bio-oil upgrading process using 9% of Mo supported with HZSM-5 as catalyst.

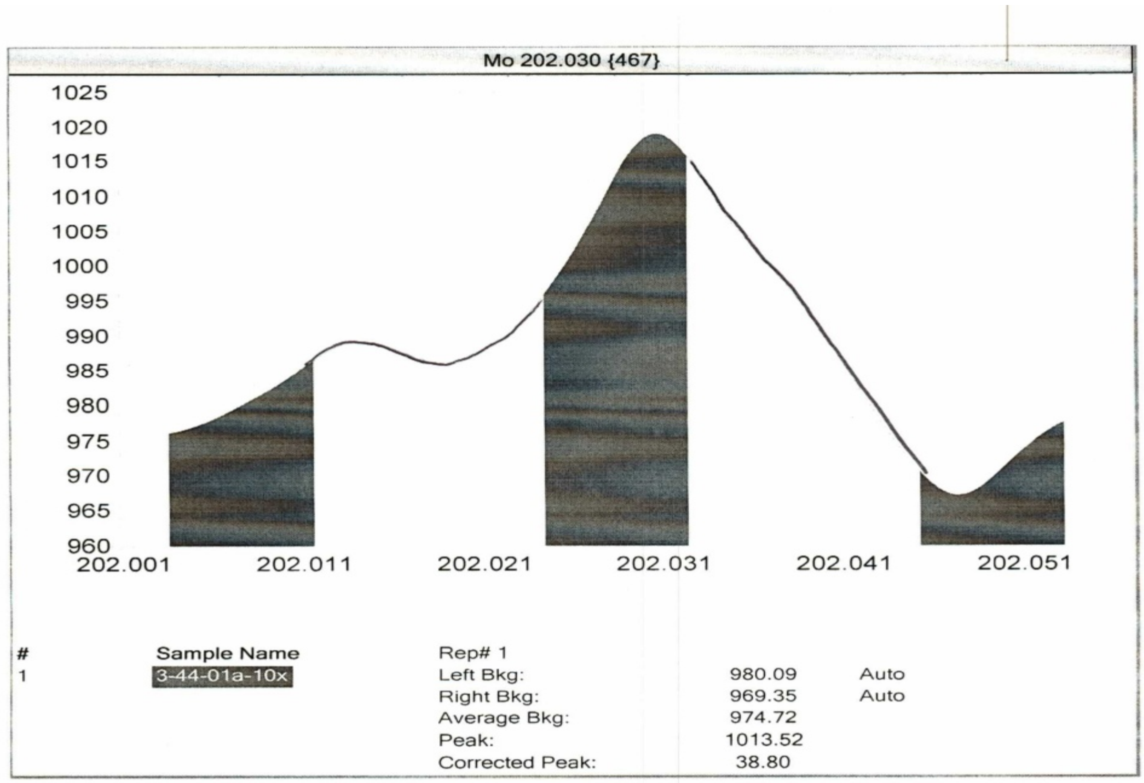


Figure 14 The ICP-OES result of Mo detection in the wastewater sample produced from sawdust bio-oil upgrading. Note: The bottom reading (numbers) is the wavelength element of choice. The left upper is the intensity of measurement.

Task 6 Education and training in the project

There were seven PhD/M.S. graduate students (Yijing Wang, Parvathi Jampani, Dan Liu, Zhongwei Liu, Xianhui Zhao, Yinbin Huang, and Wangda Qu) and two postdocs (Yang Gao and Chunkai Shi) have been involved in the projects. The students (Xianhui Zhao, Yinbin Huang, and Wangda Qu) and two Postdocs were supported by the funds from DOE (DE-FG36-08GO88073) and USDA projects (2011-67009-20030). They have been working on the biomass pyrolysis and bio-oil upgrading. The PhD student (Zhongwei Liu) mainly focused on wastewater collection and characterization.

Project outcomes and challenges

The outcomes of this project included:

- Completed catalytic upgrading of sawdust bio-oil and sunflower oil to drop in fuels.
- Collected the wastewater samples and completed the characterization of the wastewater.
- Used the preliminary data in a new proposal to apply for USDA NIFA research funding.
- Trained seven PhD/M.S. graduate students and two postdocs for bio-refinery and wastewater evaluation research.
- Presented three presentations in the 2014 ASABE conferences.

- Suggested the wastewater produced from biomass pyrolysis and bio-oil upgrading should be properly treated before release to environment due to the heavy metal (Mo) residues found in the wastewater.

Huang, Y., L. Wei, J. Julson, 2014. Upgrading of bio-oil into advanced bio-fuel over Mo/H-ZSM5 catalysts. *The ASABE/CSBE North-Central Intersectional Meeting***,** March 28-29, Brookings, SD.

Z. Liu, L. Wei, T. Trooien, Y. Huang, X. Zhao, Y. Gao, 2014. Characterization of wastewater produced in pyrolysis bio-oil production and upgrading for recovery of organic acids. *The ASABE/CSBE North-Central Intersectional Meeting*, March 28-29, Brookings, SD

Liu, Z., L. Wei, Y. Huang, Todd Trooien, investigation of wastewater produced from corn stover and sawdust pyrolysis, ASABE/CSAE Intersectional annual meeting, 2014, July 17 - 21, Montreal, Canada.

Evaluating the Nitrate-Removal Effectiveness of Denitrifying Bioreactors (part 2)

Basic Information

Title:	Evaluating the Nitrate-Removal Effectiveness of Denitrifying Bioreactors (part 2)
Project Number:	2013SD226B
Start Date:	3/1/2013
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	South Dakota First
Research Category:	Water Quality
Focus Category:	Agriculture, Non Point Pollution, None
Descriptors:	None
Principal Investigators:	Jeppe H Kjaersgaard, Christopher Hay, Todd P. Trooien

Publications

1. Kjaersgaard, J., 2013. Denitrifying Bioreactors for N Removal from Tile Drainage Water. NDCDEA, ND/SD 319 Coordinators Meeting, Bismarck, ND, March 20-21 2013.
2. Partheeban, C., Kjaersgaard, J., Hay, C., Trooien, T., 2013. Demonstrating the Nitrogen-removal Effectiveness of Denitrifying Bioreactors for Improved Drainage Water Management. Eastern South Dakota Water Conference, Brookings, SD. October 30 2013.
3. Partheeban, C., Kjaersgaard, J., Hay, C., Trooien, T., 2013. Demonstrating the Nitrogen-removal Effectiveness of Denitrifying Bioreactors for Improved Drainage Water Management. Eastern South Dakota Water Conference, Brookings, SD. October 30 2013.
4. Partheeban, C., Kjaersgaard, J., Hay, C., Trooien, T., 2013. Demonstrating the Nitrogen-removal Effectiveness of Denitrifying Bioreactors in South Dakota for Improved Drainage Water Management. ASA, CSSA, and SSSA International Annual Meeting, Tampa, FL, November 3-6 2013.
5. Kjaersgaard, J., 2013. Denitrifying Bioreactors for N Removal from Tile Drainage Water. NDCDEA, ND/SD 319 Coordinators Meeting, Bismarck, ND, March 20-21 2013.
6. Partheeban, C., Kjaersgaard, J., Hay, C., Trooien, T., 2013. Demonstrating the Nitrogen-removal Effectiveness of Denitrifying Bioreactors for Improved Drainage Water Management. Eastern South Dakota Water Conference, Brookings, SD. October 30 2013.
7. Partheeban, C., Kjaersgaard, J., Hay, C., Trooien, T., 2013. Demonstrating the Nitrogen-removal Effectiveness of Denitrifying Bioreactors for Improved Drainage Water Management. Eastern South Dakota Water Conference, Brookings, SD. October 30 2013.
8. Partheeban, C., Kjaersgaard, J., Hay, C., Trooien, T., 2013. Demonstrating the Nitrogen-removal Effectiveness of Denitrifying Bioreactors in South Dakota for Improved Drainage Water Management. ASA, CSSA, and SSSA International Annual Meeting, Tampa, FL, November 3-6 2013.
9. Partheeban, C., Kjaersgaard, J., Hay., C., Trooien, T., 2014. A Review of the factors controlling the performance of denitrifying woodchip bioreactors. 2014 ASABE Intersectional Meeting, Brookings, SD, March 28-29 2014. 10 p.
10. Partheeban, C., Kjaersgaard, J., Hay., C., Trooien, T., 2014. Demonstrating the nitrogen removal effectiveness of denitrifying bioreactors for improved drainage water management in South Dakota. 2014 ASABE and CSBE/SCGAB Annual International Meeting, Montreal, Quebec, Canada, July

13-16 2014. 11 p.

11. Partheeban, C., Karki, G., Khand, K., Cortus, S., Kjaersgaard, J., Hay, C., Trooien, T. 2014. Calibration of an AgriDrain Control Structure by using Generalized “V” Notch Weir Equation for Flow Measurement. Western South Dakota Hydrology Conference, Rapid City, SD, April 9 2014.
12. Partheeban, C., Kjaersgaard, J., Hay., C., Trooien, T., 2014. A review of agricultural practices and technologies to reduce the nitrate nitrogen load in tile drainage water. The 8th International Student Prairie Conference on Environmental Issues. Fargo, ND, August 6-8 2014.
13. Partheeban, C., Karki, G., Khand, K., Cortus, S., Kjaersgaard, J., Hay, C., Trooien, T. 2014. Calibration of an AgriDrain Control Structure by using Generalized “V” Notch Weir Equation for Flow Measurement. Western South Dakota Hydrology Conference, Rapid City, SD, April 9, 2014.
14. Partheeban, C., Kjaersgaard, J., Hay., C., Trooien, T., 2014. A review of agricultural practices and technologies to reduce the nitrate nitrogen load in tile drainage water. The 8th International Student Prairie Conference on Environmental Issues. Fargo, ND, August 6-8 2014.

Demonstrating the Nitrogen-Removal Effectiveness of Denitrifying Bioreactors for Improved Drainage Water Management

Progress Report: March 1, 2013 to February 28, 2014.

By C. Partheeban and J. Kjaersgaard, South Dakota State University. May 2014.

Report submitted to the South Dakota Water Resources Institute under the USGS 104b program.

Introduction.

The hypoxic zone of northern Gulf of Mexico (NGOM) is the largest in the USA and the second largest in worldwide (EPA-SAB, 2007). Enrichment of nutrients beyond the natural levels into the aquatic systems causes dramatic growth of algae, increased primary production, and the accumulation of organic matter which increases the greater demand for oxygen (Diaz & Rosenberg, 2008). The Mississippi River basin is the major contributor of freshwater and nutrient to the northern Gulf of Mexico. A large proportion of the nutrients enter into the Mississippi river basin from crop land through the tile drainage systems and surface runoff (EPA-SAB, 2007). Agricultural subsurface tile drainage helps to increase the agricultural productivity by allowing timely field operations and creating well aerated soil conditions to enhance the plant uptake of nutrients and reduce the surface runoff water quality issues (Crumpton & Helmers, 2004; OSU-Extension, 1998). However, the nitrate-nitrogen content of the tile water is a major environmental and health concern. Previous studies show that nitrogen fertilizer management alone is not sufficient to reduce the nitrate concentration in tile drain water (Dinnes et al., 2002). Therefore, there is an urgent and critical need to develop additional approaches to reduce the nitrate nitrogen loads in the tile drainage water before it exits the drainage systems. To reduce the nitrate accumulation and to cease the nitrogen cascade, nitrates can be converted back to inert nitrogen gas through the multi-step process called denitrification (Galloway et al., 2003).

Denitrifying woodchip bioreactors are examples of a cost effective and simple edge-of-field approach to treat the drainage water for nitrate concentration (Laura Elizabeth Christianson, 2011). Several bioreactors have been installed within the last decade or so in the US Midwest and internationally e.g. New Zealand (Schipper, Robertson, Gold, Jaynes, & Cameron, 2010). A study in Iowa by Christianson (2011) showed approximately 43% of nitrate nitrogen concentration reduction obtained by denitrifying bioreactors. Schipper et al. (2010) has investigated that both denitrification walls and denitrification beds have an ability to remove nitrate effectively with nitrate removal rates ranging from 0.01 to 3.6 g N/m3/day for walls and 2 to 22 g N/m3/day for beds. Denitrification walls mean construction of wall (generally filled with saw dust and soil mix) vertically across the groundwater flow, and denitrification beds refers to containers which are filled with carbon materials and contaminated drainage water runs out through it. This is called denitrifying bioreactors (Schipper et al., 2010; Schmidt & Clark, 2012). Although a number of investigations explain the bioreactor performance, there is still a lack of information about the effectiveness, factors controlling the bioreactor performance, site suitability, and the challenges and possible side effects of using bioreactors (Schipper et al., 2010). The objectives of this project are to demonstrate and evaluate of field scale bioreactor design by installing, monitoring, analyzing and documenting their effectiveness for removing nitrate from the subsurface drainage water in eastern South Dakota, and to estimate the cost per pound of nitrate removed and cost of nitrate removed from the tile water based on the treatment area per year.

Denitrifying woodchip bioreactors

Earlier, biological waste water treatment was practiced with the concept of denitrification reaction under anaerobic conditions where municipality and industrial wastes consisted of soluble organic impurities (Mittal, 2011). In 1988, a study was carried out to treat the groundwater based on denitrification where groundwater was pumped out and sent to reactors containing organic matter (mixture of straw), then the water was redistributed into aquifers through the soil (Boussaid, Martin, & Morvan, 1988). Same principle behind the denitrifying woodchip bioreactors can be employed in agricultural fields to remove nitrate from tile drain water.

A denitrifying bioreactor is a trench in the ground filled with labile carbonaceous materials to allow colonization of denitrifying bacteria under anaerobic conditions. The anaerobic bacteria convert the nitrate in the drainage water to inert nitrogen gas through the multi-step process called denitrification (Figure.1). Commonly, denitrification reactions are carried out by facultative anaerobic heterotrophs, such as Pseudomonas sp., that use nitrate for their respiration process to obtain oxygen (energy) using organic carbon as the electron donor (Blowes, Robertson, Ptacek, & Merkley, 1994; Rivett, Buss, Morgan, Smith, & Bemment, 2008). Thus, inoculation of microbes is not necessary for the bioreactor operation. However, studies suggest surface soil can be randomly mixed with woodchips to act as a microbial inoculant (Jaynes, Kaspar, Moorman, & Parkin, 2008; Rodriguez, 2010). Blowes et al. (1994) first carried out the application of denitrifying bioreactors in the agricultural environment in Ontario, Canada. He used barrels containing organic materials partially buried in a stream bank. Four different types of materials including sand (control), grow bark, woodchips and composted leaf material with different ratios were used as organic sources. They suggested that nitrate concentration of 3-6 mg/l was successfully reduced to below 0.02 mg/l through these bioreactors. Subsequent studies have confirmed that denitrifying bioreactors are cost effective, simple edge-of-field technology to effectively remove the nitrate from tile drain water with minimal land required (Driel, W.D.Robertson, & L.C.Merkley, 2006; Schipper et al., 2010).

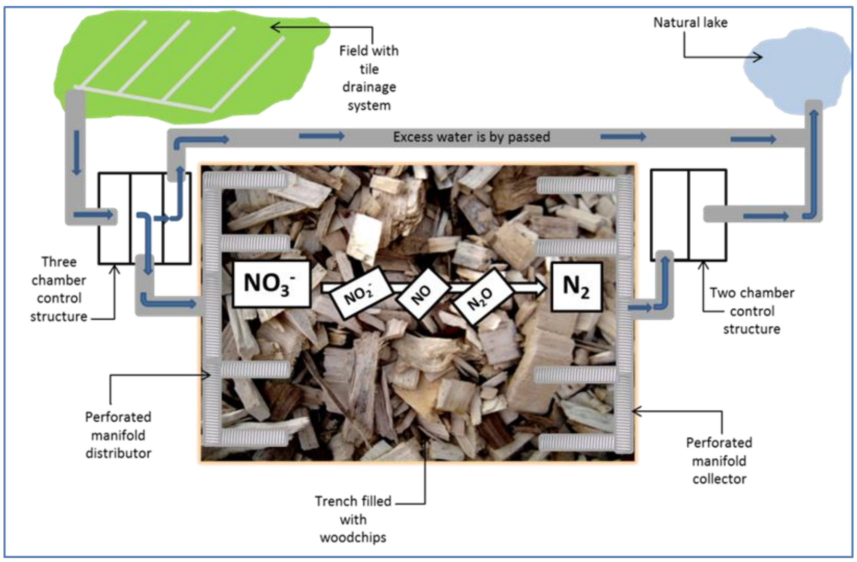


Figure 1. Plan view of schematic of woodchip bioreactor plan view (not in scale)

Bioreactor design

Two main design criteria for the dimensions of a bioreactor are the design flow rate and the design retention time. The design method is optimized for maximum nitrate removal capacity and cost efficiency. One of the major design challenges is the fluctuation of drainage flow rates throughout the year. Oftentimes, the drainage water system is not running at full capacity but at some lower, unknown flow rate. Flow rates during the year vary widely depending on changes in the field water balance components, such as after precipitation events (Laura Elizabeth Christianson, 2011). Handling the peak flow rate during the heavy rainfall events or after snowmelt is a challenge when designing a bioreactor (Driel et al., 2006). Designing a bioreactor to handle the entire volume of water at peak flow would result in an uneconomically large installation. When treating the whole water in the larger bioreactors by either increaseing the design flow rate or the retention time into the bioreactor; it results in a high extent of nitrate removal, but it has a lower removal rate (L. Christianson, Christianson, Helmers, Pederson, & Bhandari, 2013). Thus, studies suggest designing the bioreactor to treat approximately 20% of the peak flow is appropriate, which provides treatment of the majority of drained water (approximately 70%) (Laura

E. Christianson, Bhandari, Helmers, & Clair, 2009; Driel et al., 2006).

Methods and materials

Installation of bioreactors

We have installed three bioreactors in different locations in Eastern South Dakota. During 2012, we installed two bioreactors: one near Baltic, SD and one near Montrose, SD. In 2013, we installed another bioreactor near Arlington, SD.

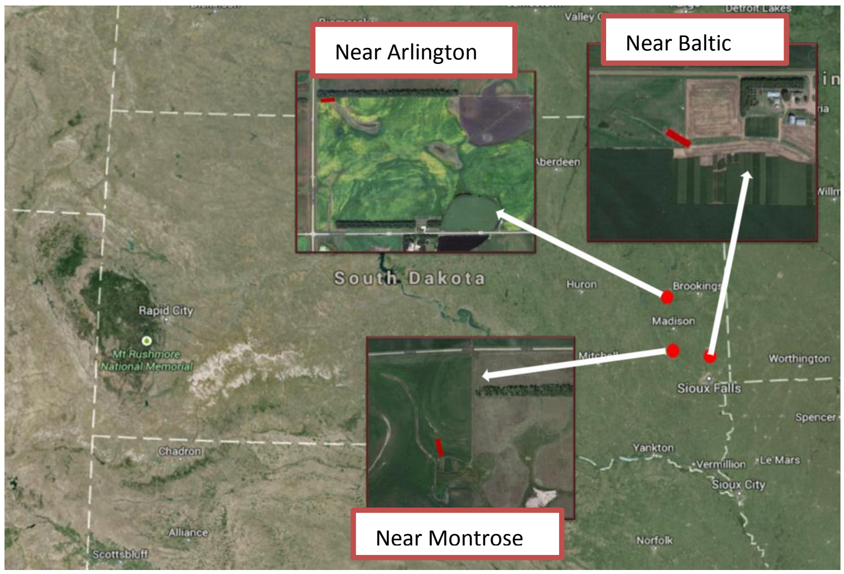


Figure 2. Approximate locations of three bioreactors installed in eastern SD (Background map: Google earth)

Bioreactor installation process

A trench was excavated with the dimensions based on the design criteria. The trench was lined with a black plastic sheeting to prevent movement of water through the bottom or the sides of the trench. Perforated PVC distribution/collector pipes were placed at both ends which were connected to the control structure by solid PVC pipes. The trench was filled with woodchips up to 3 ft. Hardwood woodchips of ¼ inch to 2 inch in size were used for this purpose. We used between 200 and 250 cu. yards of woodchips per bioreactor. the woodchips were then covered with geo-textile fabric material before covering with top soil. The geotextile fabric material allows gas to escape and prevents the woodchips from being contaminated by soil. Drainage control structures were installed to divert water through the trench and control the water entrance into the trench as per the design criteria.

Installation of monitoring equipment

Monitoring equipment was installed near both the upstream and the downstream control structure to measure meteorological information and water quality data. At the Baltic bioreactor, sensors were connected with a data-logger (CS CR1000) to collect and store the data every 10 minutes. Data was downloaded from the data-logger during the field visits. Desiccated case (A150, Campbell scientific product) was used to extend the cable downstream from the data-logger to install a pressure transducer at the downstream control structure. "Logger net" software was used to create program for the data-logger to communicate with the sensors. At the Montrose site, Decagon sensors were used to measure the meteorological and water quality data. Two separate data-loggers (Em50) were installed near the upstream and downstream control structures. In Arlington, we installed "Decagon" made sensors connected with "Campbell scientific" made data logger.

Water sampling and analysis

Water samples were collected from the upstream and downstream control structures in each bioreactor on the same day twice per week (approximately 4 days interval). To grab the water, a water bottle attached to a steel rod was used. The sample bottle was filled completely to prevent air-water reactions and placed in a cooler immediately after sampling. The collected water samples were kept refrigerated in the lab until analyzed. Water sampling was done during the end of the April 2013 to mid-July 2013.Thereafter, no water flow was observed. A spectrophotometer (DR 2800) was used to measure the concentration of nitrate nitrogen in the water sample. Total Kjehldahl Nitrogen (TKN) was measured for selected samples by South Dakota Agricultural Laboratories.

Results and Discussion

Nitrate removal

All samples were analyzed for nitrate concentration. At the Baltic bioreactor, measured nitrate concentrations from the outlet water at most of the sampling events were less than 10 ppm which is the threshold level for drinking water quality (WHO, 2011) except at a few instances (Figure. 3). The relative water flow rate and the rainfall amounts were during the flow period is shown in Figure 4. We observed frequent rainfall events from the end of the April to early June, 2013. Even during this period, a small spike of flow rate was observed. This is because soil pores were filled with water. During mid-June, due to the high intensity of rainfall, high fluctuation of flow was observed. High flow through the bioreactor results in less nitrate removal due to the insufficient retention time for the water inside the reactor. Again during early July, there was larger rainfall event (Figure. 4) which did not result in any increases in flow rate as the growing crop had depleted some of the soil moisture.

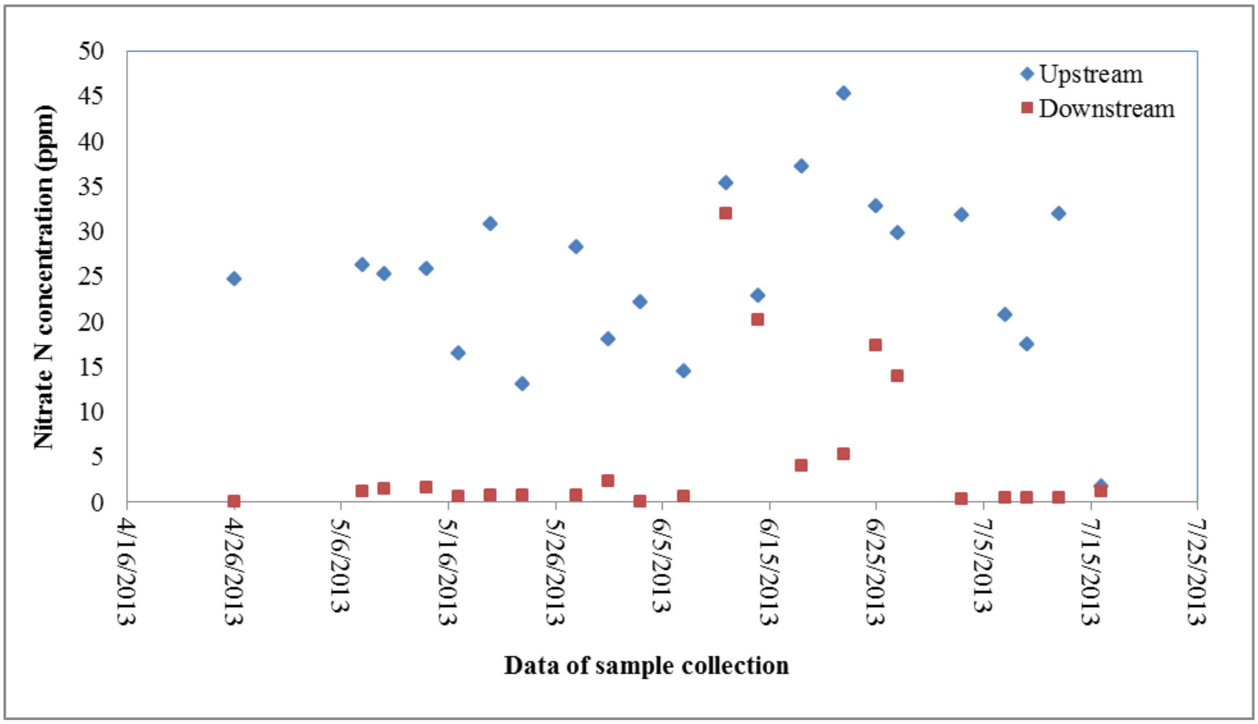


Figure 3. Nitrate N concentration of both upstream and downstream water from the Baltic site bioreactor

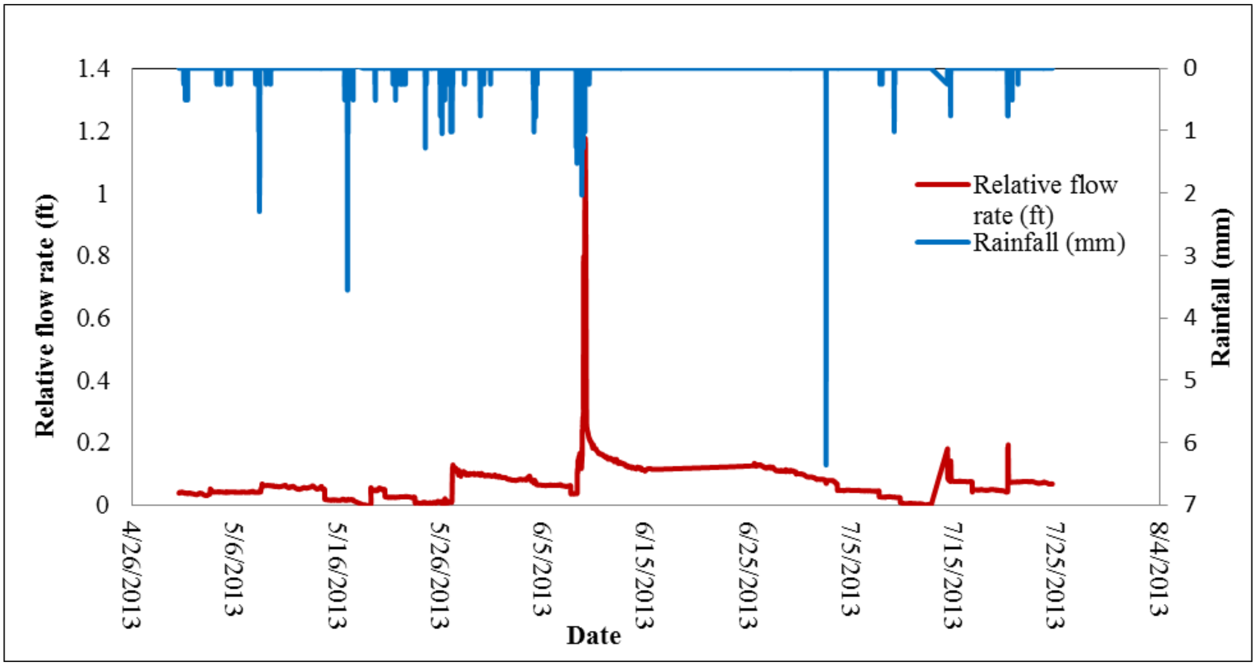


Figure 4. Relative flow rate of water through the control structure and rainfall in Baltic site bioreactor

At the Montrose bioreactor, the pattern of nitrate concentration in the water collected from the upstream control structure and the downstream control structure indicates frequent fluctuation of flow of water throughout the sampling period (early May to late July) (Figure. 5). Rainfall event history and the relative flow rate through the reactor during the sampling period are shown in Figure. 6. Compared with the Baltic site, here a high frequency of rainfall was observed. Flow rate pattern changed with rainfall pattern. During June 9 2013 to June 16 2013, flow rate data were lost due to dislodging of the sensor.

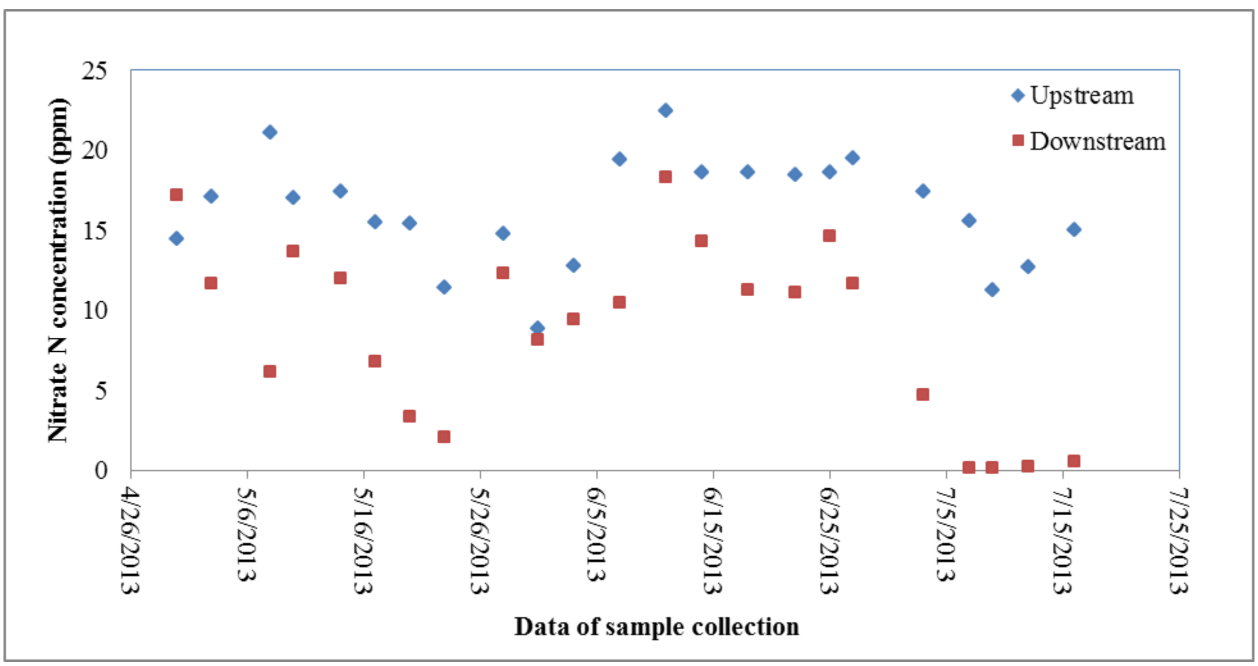
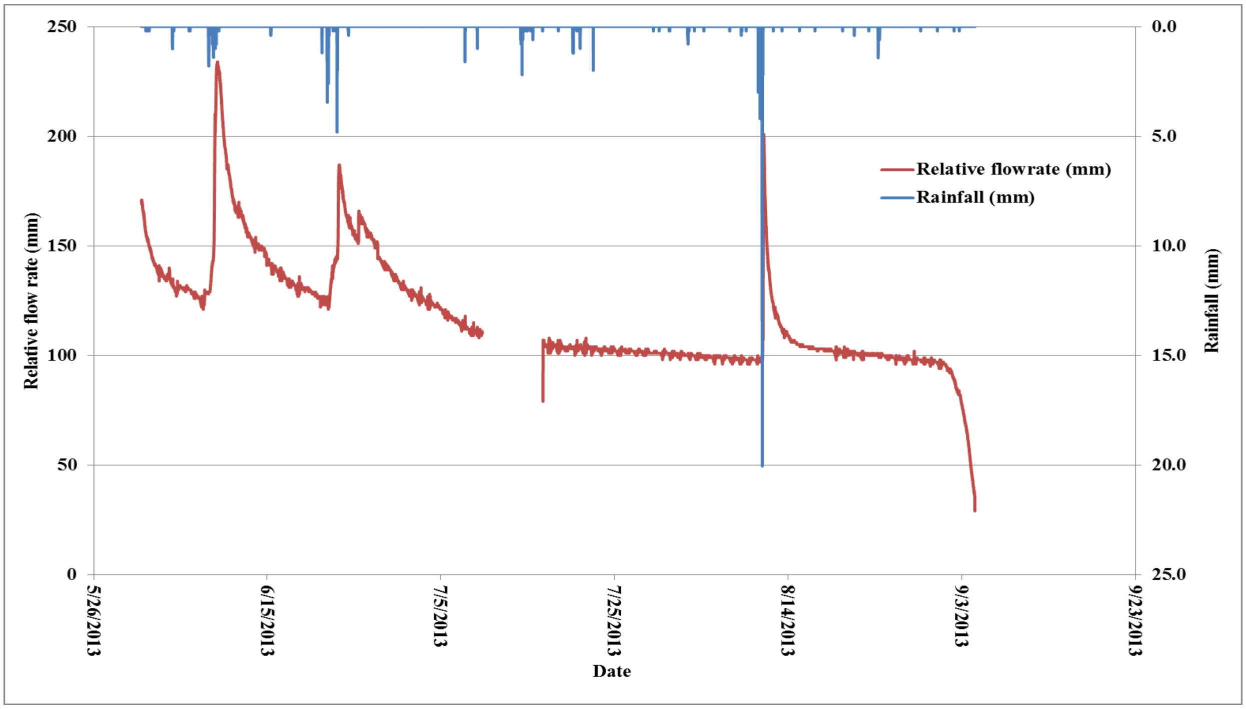


Figure 5. Nitrate N concentration of both upstream and downstream water from Montrose site bioreactor



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Factors controlling the bioreactor performance

In addition to the meteorological data, some water quality parameters, such as water temperature, electrical conductivity (EC), and relative humidity were recorded in the both Baltic and Montrose bioreactor. Temperature affects the growth rate of denitrifying organisms, with high growth rate at higher temperatures within the temperature range typically found in the soil environment (Lakha et al., 2009). In Eastern South Dakota, drainage water from the field starts to enter into the bioreactor at the temperature range from just above the freezing and around 22^{o}C. After that, during the late summer water flow through the bioreactor was ceased. Still, we had good nitrate removal performance from the bioreactor indicates denitrification occurs even below 22^{0}C. Since we had a very low temperature during the study period, we were unable to get the results of bioreactor performance based on temperature change. Multiple regression analysis was completed using SAS with the percentage reduction of nitrate as independent variable, and temperature, electrical conductivity, initial nitrate concentration, and relative flow rate as dependent variables. For the Baltic bioreactor, both temperature and initial nitrate concentration effects on percentage reduction of nitrate are not statistically significant. The effect of EC on nitrate removal percentage has positively statistically significance (with alpha 0.05). Electrical conductivity can be defined as water's ability to conduct electrical current. The EC of water is affected by the total amount of salts (ions) dissolved in the water. Here in tile drain water, the presence of nitrate ions (negative ions) facilitates the EC. The nitrate removal percentage has changed positively with EC shows concentration of nitrate plays a role in nitrate removal process while other factors such as temperature remain low. Relative flow rate however negatively affected the percentage nitrate removal significantly (it is statistically highly significant with alpha 0.01). High flow rate results in insufficient reaction time for nitrate removal.

In the Montrose bioreactor, both temperature and initial nitrate concentration effects on percentage reduction of nitrate are not statistically significant. Effect of EC and the effect of relative flow rate on the percentage removal of nitrate are statistically significant with alpha 0.05. Unfortunately, water quality parameters were not recorded at the Montrose site until during the mid-part of the sampling period.

Cost estimation

A preliminary economic analysis of the maintenance and installation costs was done for each bioreactor. The costs were estimated to treat tile drain water for nitrate normalized to a unit area (ha and ac) of field per year for each bioreactor (table 1, table 2 and table 3). Total cost for the bioreactor installation was categorized for different cost components. For each component, the life expectancy was assumed based on the previous studies regarding the lifespan of a bioreactor to calculate the cost per year. Here, we used a 4%/year interest rate was added and annual depreciation value applied.

Table 1. Cost detail for Baltic site bioreactor installation.

Cost category	Installation cost ($)	Interest (4% /yr.) ($)	Replacement period (years)	Cost per years ($)
Excavation and backfilling	1,900	798	20	135
Woodchips	3,925	1649	20	279
Plastic liner	500	210	20	36
Control structure	1,675	1374	40	76
Other (personnel transport, labor)	1,000	820	40	46
Stop logs	14	3	8	4
Total cost per year				$ 576
Total treatment area				16.2 ha
Cost per treatment area				$ 36/year/ha
				$ 14/year/ac

Table 2. Cost detail for Montrose site bioreactor installation.

Cost category	Installation cost ($)	Interest (4% /yr.) ($)	Replacement period (years)	Cost per years ($)
Excavation and backfilling	2,000	840	20	142
Woodchips	4,500	1890	20	320
Plastic liner and other supplies	1,300	546	20	92
Control structure	2,100	1722	40	96
Other (personnel transport, labor)	5,00	410	40	23
Stop logs	14	3	8	2
Total cost per year				$ 675
Total treatment area				15.4 ha
Cost per treatment area				$ 44/year/ha
				$ 18/year/ac

Table 3. Cost detail for Arlington site bioreactor installation.

Cost category	Installation cost ($)	Interest (4% /yr.) ($)	Replacement period (years)	Cost per years ($)
Excavation and backfilling	2,100	882	20	149
Woodchips	3,000	1260	20	213
Plastic liner	100	42	20	7
Control structure	2,300	1886	40	105
Other (personnel transport, labor)	4,00	328	40	18
Stop logs	14	3	8	2
Total cost per year				$ 494
Total treatment area				6.9 ha
Cost per treatment area				$ 72/year/ha
				$ 29/year/ac

Conclusion or Summary

A denitrifying woodchip bioreactor is a promising best management approach for reducing the nitrogen exports from agricultural fields into the surface waters through the tile drainage systems. In Eastern South Dakota, the average concentration-based nitrate removal at two bioreactors installed near Baltic and Montrose were 81% and 51% respectively during the 2013 season. Those values are higher than the value obtained from a study in Iowa. Since temperature is the most influencing factor for microbial activity, we had good nitrate removal across a temperature range from just above the freezing to 22^{o}C. The flow rate through the reactor significantly affected the nitrate removal percent. The effect of EC on the nitrate removal percent shows concentration of nitrate affects the nitrate removal percent. Preliminary economic analysis was done. Cost per pound of nitrate removed per volume of reactor per day will be calculated and compared with other approaches.

Acknowledgements

This project is funded by the USGS 104b program. Project collaborators include the South Dakota USDA NRCS, East Dakota Water Development District, South Dakota Soybean Research and Promotion Council, South Dakota Farm Bureau, South Dakota Corn Utilization Council, and the Vermillion Basin Water Development District whose help and support are gratefully acknowledged.

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Nutrient Removal from Agricultural Subsurface Drainage Using Denitrification Bioreactors and Phosphate Adsorbents

Basic Information

Title:	Nutrient Removal from Agricultural Subsurface Drainage Using Denitrification Bioreactors and Phosphate Adsorbents
Project Number:	2014SD235B
Start Date:	3/1/2014
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	South Dakota 1st
Research Category:	Water Quality
Focus Category:	Water Quality, Agriculture, Nutrients
Descriptors:	None
Principal Investigators:	Guanghui Hua, Christopher Hay, Jeppe H Kjaersgaard, Christopher G Schmit

Publication

1. Salo, Morgan, Weiss, Kody, Hua, Guanghui, Schmit, Christopher, Hay, Christopher, 2014, Nutrient removal from agricultural subsurface drainage using denitrification bioreactors and phosphate adsorbents. Eastern South Dakota Water Conference, Brookings, SD, October 29. (Poster Presentation)

Demonstrating the Nitrogen-Removal Effectiveness of Denitrifying Bioreactors for Improved Drainage Water Management

Project Completion Report.

By C. Partheeban and J. Kjaersgaard, South Dakota State University. May 2015.

Report submitted to the South Dakota Water Resources Institute under the USGS 104b program.

Introduction.

A hypoxic condition or "dead" zone in natural aquatic ecosystem is caused by decreased levels of dissolved oxygen where living aquatic organisms no longer survive. The hypoxic zone of the northern Gulf of Mexico (NGOM) is the largest in the USA and the second largest worldwide (EPA-SAB, 2007). The maximum area of the hypoxic zone of NGOM was measured at 22,000 km2 during the summer of 2002 (EPA-SAB, 2007). The Mississippi-Atchafalaya River basin (MARB), which is one of the largest river systems in the world, draining approximately 40% of the contiguous US (Figure 1.1), is the dominant contributor of fresh water and nutrients to NGOM. Nutrient enrichment or eutrophication is one of the major drivers for the formation of hypoxic zones. Enrichment of nutrients beyond natural levels into the aquatic systems may cause dramatic growth of algae, increased primary production, and the accumulation of organic matter which increases the demand for oxygen (Diaz and Rosenberg, 2008; EPA-SAB, 2007).

A nutrient of primary concern causing hypoxia is nitrogen. According to the USGS 58 percent of the Mississippi River basin is in crop lands, and about seven million metric tons of nitrogen fertilizer are applied annually to crop lands within the basin. The majority of nutrients enter into the Mississippi River basin from crop lands through surface runoff and subsurface flows (Goolsby and Battaglin, 2000). Nitrogen, in the form of nitrate-nitrogen, is highly soluble in water and moves readily with the soil moisture. One mechanism that is thought to increase the nitrate-nitrogen loading from crop land to the river system is tile drainage which is a common practice in the central part of the basin.

In addition to contributing the hypoxia, nitrate nitrogen is a public health concern. Too much nitrate-nitrogen (above 10 mg/L) in drinking water is considered harmful to humans, especially to young infants and pregnant women. In the human body, excessive nitrate is converted to nitrite which causes methemoglobinemia (blue baby syndrome) by restricting oxygen transport in the blood stream. Livestock, especially young animals, affected by drinking nitrate contaminated water (above 100 mg/l) react the same way as human babies (Galloway et al., 2003).

Denitrifying woodchip bioreactors are examples of a cost effective and simple edge-of-field approach to treat the drainage water for nitrate concentration (Christianson, 2011). Several bioreactors have been installed within the last decade or so in the US Midwest and internationally e.g. New Zealand (Schipper, Robertson, Gold, Jaynes, & Cameron, 2010). A study in Iowa by Christianson (2011) showed approximately 43% of nitrate nitrogen concentration reduction obtained by denitrifying bioreactors. Schipper et al. (2010) has investigated that both denitrification walls and denitrification beds have an ability to remove nitrate effectively with nitrate removal rates ranging from 0.01 to 3.6 g N/m3/day for walls and 2 to 22 g N/m3/day for beds. Denitrification walls mean construction of wall (generally filled with saw dust and soil mix) vertically across the groundwater flow, and denitrification beds refers to containers which are filled with carbon materials and contaminated drainage water runs out through it. This is called denitrifying bioreactors (Schipper et al., 2010; Schmidt & Clark, 2012). Although a number of investigations explain the bioreactor performance, there is still a lack of information about the effectiveness, factors controlling the bioreactor performance, site suitability, and the challenges and possible side effects of using bioreactors (Schipper et al., 2010). The objectives of this project are to demonstrate and evaluate of field scale bioreactor design by installing, monitoring, analyzing and documenting their effectiveness for removing nitrate from the subsurface drainage water in eastern South Dakota, and to estimate the cost per pound of nitrate removed and cost of nitrate removed from the tile water based on the treatment area per year.

Denitrifying woodchip bioreactors

A denitrifying bioreactor is a trench in the ground filled with labile carbonaceous materials to allow colonization of denitrifying bacteria under anaerobic conditions. The anaerobic bacteria convert the nitrate in the drainage water to inert nitrogen gas through the multi-step process called denitrification (Figure.1). Commonly, denitrification reactions are carried out by facultative anaerobic heterotrophs, such as Pseudomonas sp., that use nitrate for their respiration process to obtain oxygen (energy) using organic carbon as the electron donor (Blowes, Robertson, Ptacek, & Merkley, 1994; Rivett, Buss, Morgan, Smith, & Bemment, 2008). Thus, inoculation of microbes is not necessary for the bioreactor operation. However, studies suggest surface soil can be randomly mixed with woodchips to act as a microbial inoculant (Jaynes, Kaspar, Moorman, & Parkin, 2008; Rodriguez, 2010). Several bioreactors have been installed within the last decade or so in the US Midwest and internationally, e.g. New Zealand (Schipper et al., 2010) and Canada (Blowes et al., 1994). Many of these installations are part of studies investigating the effectiveness of nitrate removal by the denitrifying woodchip bioreactors under different climate, soil, and tile flow regimes. A study in Iowa by Christianson (2011) showed approximately 43% nitrate nitrogen concentration reduction by denitrifying bioreactors. Schipper et al (2010) found that both denitrification walls and denitrification beds (denitrifying bioreactor) have the ability to remove nitrate effectively with nitrate removal rates ranging from 0.01 to 3.6 g N/m3/day for walls and 2 to 22 g N/m3/day for beds. A denitrification wall refers to the construction of a subsurface permeable wall (generally filled with saw dust and soil mix) vertically intercepting subsurface shallow groundwater flow. Denitrification beds are containers filled with carbon materials and contaminated drained water runs out through it (Schipper et al., 2010; Schmidt and Clark, 2012). Although a number of investigations have reported performance information of bioreactors in removing nitrate nitrogen, there is still a lack of information about the effectiveness of bioreactors across different climates, soil and tile conditions, factors controlling the bioreactor performance, site suitability, and the challenges and possible unintended side effects of using bioreactors (Schipper et al., 2010).

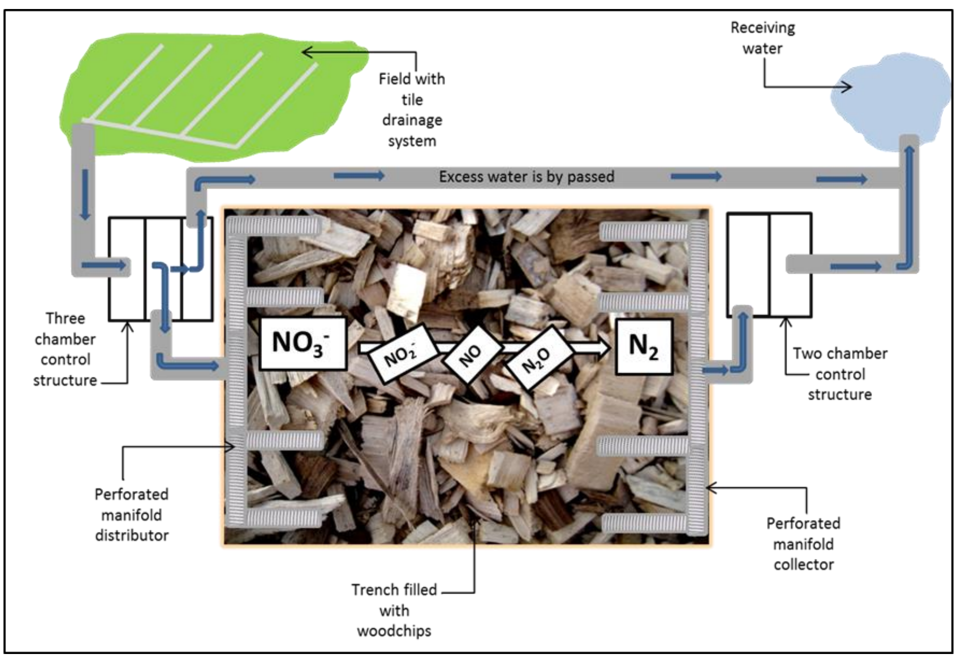


Figure 1. Plan view of schematic of woodchip bioreactor plan view (not in scale)

Bioreactor design

Two main design criteria for the dimensions of a bioreactor are the design flow rate and the design retention time. The design method is optimized for maximum nitrate removal capacity and cost efficiency. One of the major design challenges is the fluctuation of drainage flow rates throughout the year. Oftentimes, the drainage water system is not running at full capacity but at some lower, unknown flow rate. Flow rates during the year vary widely depending on changes in the field water balance components, such as after precipitation events (Christianson, 2011). Handling the peak flow rate during the heavy rainfall events or after snowmelt is a challenge when designing a bioreactor (Driel et al., 2006). Designing a bioreactor to handle the entire volume of water at peak flow would result in an uneconomically large installation. When treating the whole water in the larger bioreactors by either increaseing the design flow rate or the retention time into the bioreactor; it results in a high extent of nitrate removal, but it has a lower removal rate (L. Christianson, Christianson, Helmers, Pederson, & Bhandari, 2013). Thus, studies suggest designing the bioreactor to treat approximately 20% of the peak flow is appropriate, which provides treatment of the majority of drained water (approximately 70%) (Laura E. Christianson, Bhandari, Helmers, & Clair, 2009; Driel et al., 2006).

Methods and materials

Installation of bioreactors

We have installed three bioreactors in different locations in Eastern South Dakota. During 2012, we installed two bioreactors: one near Baltic, SD and one near Montrose, SD. In 2013, we installed another bioreactor near Arlington, SD.

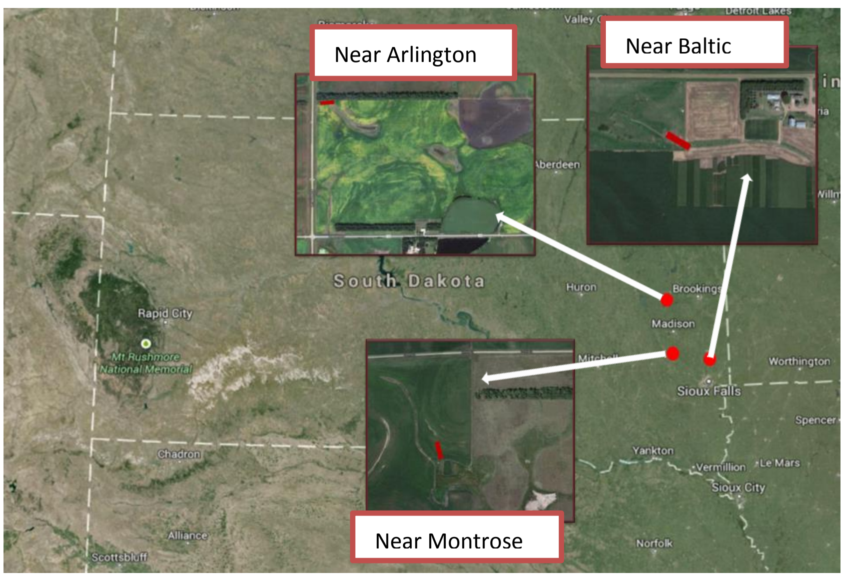


Figure 2. Approximate locations of three bioreactors installed in eastern SD (Background map: Google earth)

Bioreactor installation process

A trench was excavated with the dimensions based on the design criteria. The trench was lined with a black plastic sheeting to prevent movement of water through the bottom or the sides of the trench. Perforated PVC distribution/collector pipes were placed at both ends which were connected to the control structure by solid PVC pipes. The trench was filled with woodchips up to 3 ft. Hardwood woodchips of ¼ inch to 2 inch in size were used for this purpose. We used between 200 and 250 cu. yards of woodchips per bioreactor. the woodchips were then covered with geo-textile fabric material before covering with top soil. The geotextile fabric material allows gas to escape and prevents the woodchips from being contaminated by soil. Drainage control structures were installed to divert water through the trench and control the water entrance into the trench as per the design criteria.

Installation of monitoring equipment

Monitoring equipment was installed near both the upstream and the downstream control structure to measure meteorological information and water quality data. At the Baltic bioreactor, sensors were connected with a data-logger (CS CR1000) to collect and store the data every 10 minutes. Data was downloaded from the data-logger during the field visits. Desiccated case (A150, Campbell scientific product) was used to extend the cable downstream from the data-logger to install a pressure transducer at the downstream control structure. “Logger net” software was used to create program for the data-logger to communicate with the sensors. At the Montrose site, Decagon sensors were used to measure the meteorological and water quality data. Two separate data-loggers (Em50) were installed near the upstream and downstream control structures. In Arlington, we installed “Decagon” made sensors connected with “Campbell scientific” made data logger.

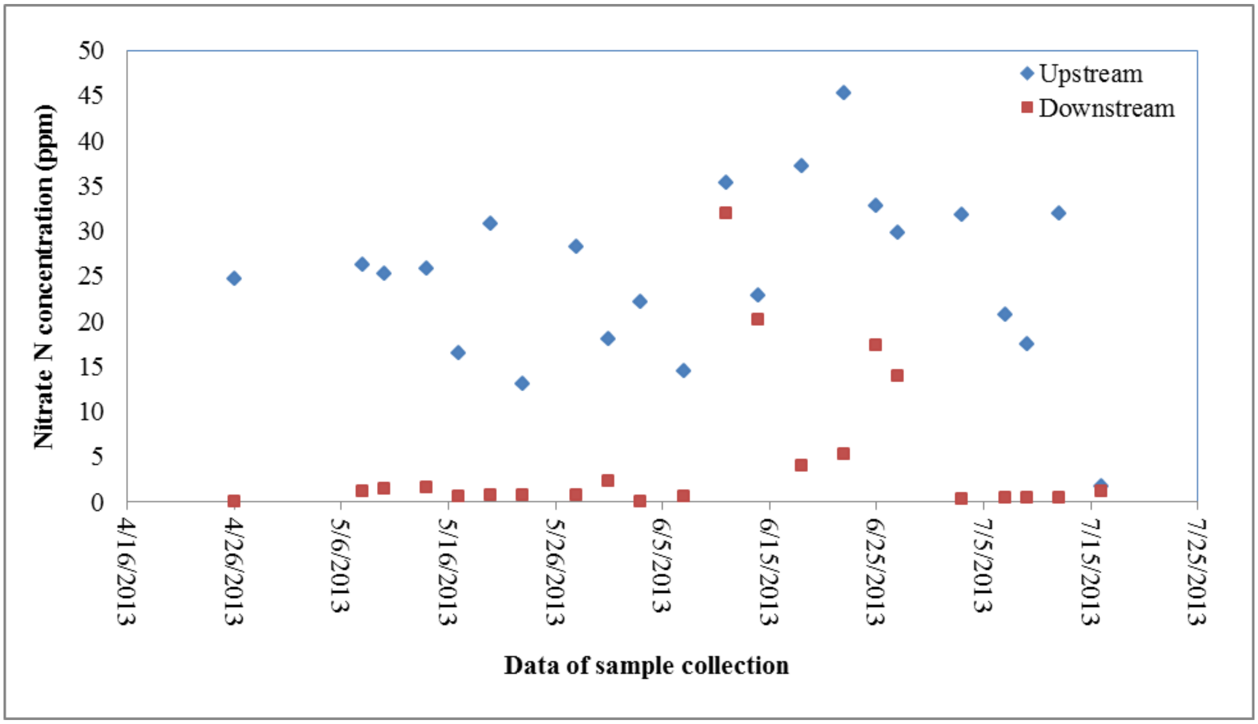
Water sampling and analysis

Water samples were collected from the upstream and downstream control structures in each bioreactor on the same day twice per week (approximately 4 days interval). To grab the water, a water bottle attached to a steel rod was used. The sample bottle was filled completely to prevent air-water reactions and placed in a cooler immediately after sampling. The collected water samples were kept refrigerated in the lab until analyzed. Water sampling was done during the end of the April 2013 to mid-July 2013.Thereafter, no water flow was observed. A spectrophotometer (DR 2800) was used to measure the concentration of nitrate nitrogen in the water sample. Total Kjehldahl Nitrogen (TKN) was measured for selected samples by South Dakota Agricultural Laboratories.

Results and Discussion

Nitrate removal

All samples were analyzed for nitrate concentration. At the Baltic bioreactor, measured nitrate concentrations from the outlet water at most of the sampling events were less than 10 ppm which is the threshold level for drinking water quality (WHO, 2011) except at a few instances (Figure. 3). The relative water flow rate and the rainfall amounts were during the flow period is shown in Figure 4. We observed frequent rainfall events from the end of the April to early June, 2013. Even during this period, a small spike of flow rate was observed. This is because soil pores were filled with water. During mid-June, due to the high intensity of rainfall, high fluctuation of flow was observed. High flow through the bioreactor results in less nitrate removal due to the insufficient retention time for the water inside the reactor. Again during early July, there was larger rainfall event (Figure. 4) which did not result in any increases in flow rate as the growing crop had depleted some of the soil moisture.



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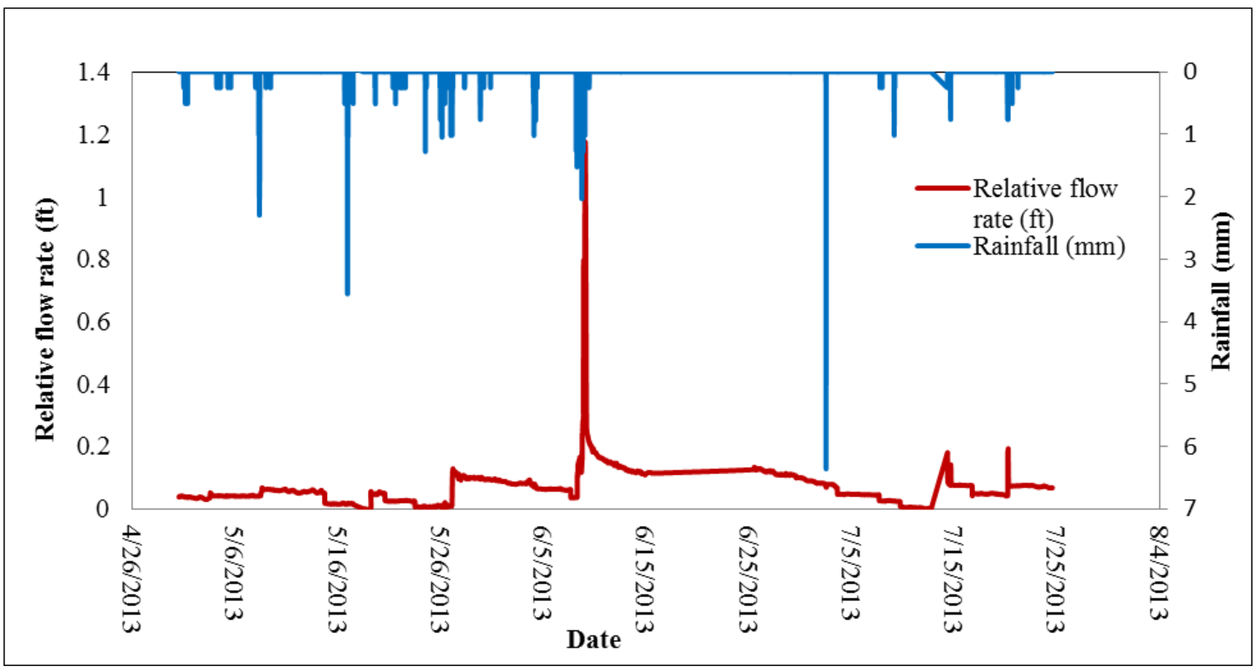

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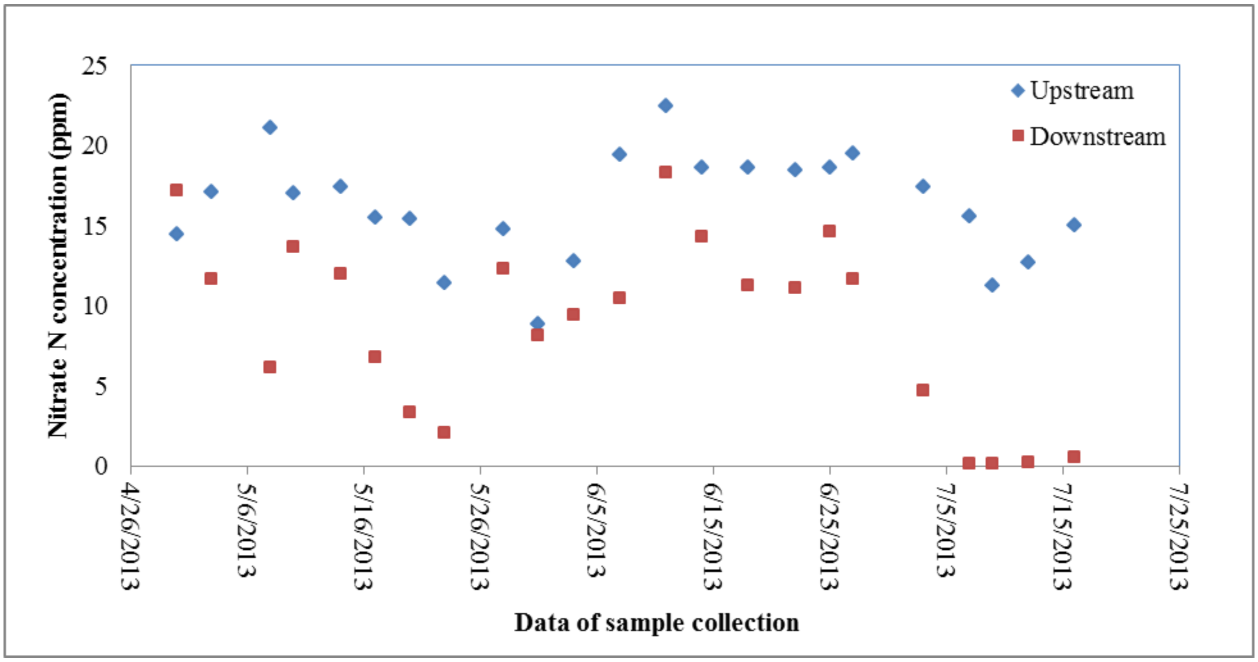

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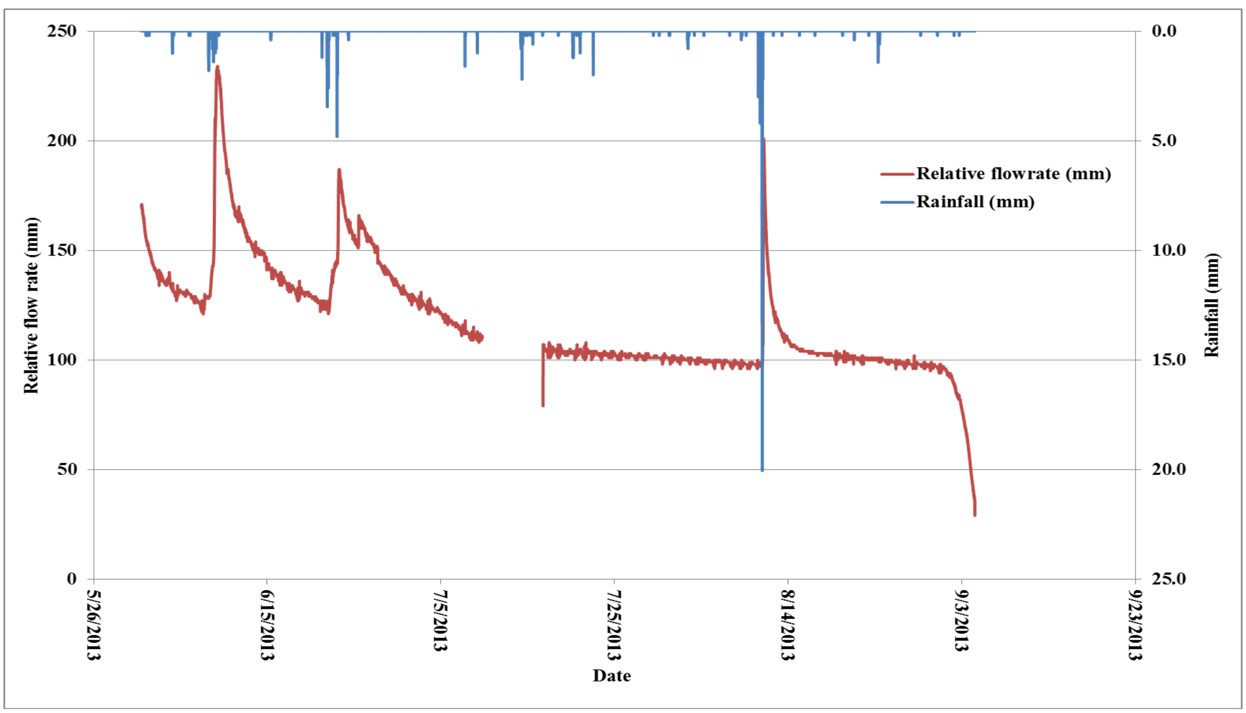

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Plastic liner and other supplies	1,300	546	20	92
Control structure	2,100	1722	40	96
Other (personnel transport, labor)	5,00	410	40	23
Stop logs	14	3	8	2
Total cost per year				$ 675
Total treatment area				15.4 ha
Cost per treatment area				$ 44/year/ha
				$ 18/year/ac

Table 3. Cost detail for Arlington site bioreactor installation.

Cost category	Installation cost ($)	Interest (4% /yr.) ($)	Replacement period (years)	Cost per years ($)
Excavation and backfilling	2,100	882	20	149
Woodchips	3,000	1260	20	213
Plastic liner	100	42	20	7
Control structure	2,300	1886	40	105
Other (personnel transport, labor)	4,00	328	40	18
Stop logs	14	3	8	2
Total cost per year				$ 494
Total treatment area				6.9 ha
Cost per treatment area				$ 72/year/ha
				$ 29/year/ac

Summary

The average concentration based percent nitrate-nitrogen reduction was 81%, 51%, and 96% from the bioreactors of Baltic, Montrose, and Arlington respectively. Those values are comparable with previous bioreactor studies in other states and in other countries. Flows in the Montrose bioreactor were more variable, and the average percent nitrate-nitrogen concentration reduction in Montrose was lower than in Baltic. There was an insufficient data from the Arlington bioreactor to draw conclusion. Leaching of organic matter and organic N were found at all three bioreactors during the beginning period after the installation (around two to four weeks). The calculated average removal rate of nitrate-nitrogen per unit volume of woodchips (unit volume of bioreactor) is 0.98 g N/m3/d, which is comparable with results from the study about the bioreactor in Iowa by Christianson et al. (2012a). The calculated average removal rate of nitrate-nitrogen in unit active flow volume of bioreactor is 12.58 g N/m3/d.

From the economic analysis results obtained here and from previous research, the denitrifying woodchip bioreactor is comparatively cost effective to other reduction practices. Bioreactors have the advantages of requiring little land, and they are simple practices. The installation costs for our bioreactors reflect the costs a producer or a land owner would face using local suppliers and service providers. The costs could be reduced if a producer owns the appropriate equipment for the earth work or other installation activities, or if woodchips can be obtained from an inexpensive local source.

Acknowledgements

This project is funded by the USGS 104b program. Project collaborators include the South Dakota USDA NRCS, East Dakota Water Development District, South Dakota Soybean Research and Promotion Council, South Dakota Farm Bureau, South Dakota Corn Utilization Council, and the Vermillion Basin Water Development District whose help and support are gratefully acknowledged.

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Evaluating Nutrient Best Management Practices to Conserve Water Quality

Basic Information

Title:	Evaluating Nutrient Best Management Practices to Conserve Water Quality
Project Number:	2014SD236B
Start Date:	3/1/2014
End Date:	2/28/2016
Funding Source:	104B
Congressional District:	South Dakota 1st
Research Category:	Water Quality
Focus Category:	Water Quality, Agriculture, Non Point Pollution
Descriptors:	None
Principal Investigators:	Laurent M. Ahiablame, Laurent M. Ahiablame, Sandeep Kumar

Publications

There are no publications.

Evaluating Nutrient Best Management Practices to Conserve Water Quality

Progress Report: March 1, 2014 to February 28, 2015.

By Laurent Ahiablame, South Dakota State University (on February 20, 2015).

Report submitted to the South Dakota Water Resources Institute under the USGS 104b program.

Project Objective:

The overall objective of this project is to demonstrate and evaluate BMPs to minimize the water quality impacts from winter manure spreading by reducing the nitrogen, phosphorus, sediment, and E. coli exports due to surface runoff. The specific objectives are:

1. Compare in-field manure placement practices during winter spreading to determine which practice that minimizes the impact on water quality and develop BMPs,
2. Assess climatic risk factors using frequency of soil frost and rainfall events impacting runoff and water quality and monitor changes in soil nutrient levels,
3. Characterize runoff and erosion behavior in the watersheds and extrapolate to other locations in eastern South Dakota using computer-based agro-ecosystem modeling,
4. Provide education on winter manure spreading BMPs to producers, extension educators, crop advisers, land managers, conservation agencies including the NRCS, state regulators, and other stakeholders.

Brief Summary of What Has Been Accomplished:

- We hired Ms. Shikha Singh as a graduate research assistant to work on this project. Ms. Singh is currently pursuing a MS degree in the Department of Plant Science at SDSU. Ms. Singh will help with field runoff and water quality monitoring, and use the data to further characterize runoff and erosion behavior at the study site using computer-based modeling.
- We are conducting a comprehensive literature review on water quality impacts from winter manure spreading with respect to nitrogen, phosphorus, sediment, and E. coli exports in surface runoff.
- We are collecting runoff flow rate with time, runoff volume, runoff constituent concentrations (i.e. Total N, NO_3-N, NH_4-N, total P, dissolved P), rainfall, air temperature (locally), wind speed and solar radiation (at the closest weather station), and soil water content at 3 different depths at 5 locations within the field.
- Experimental treatments applied at the study site consist of:
    1. Manure applied in late winter/early spring to the top 1/2 of the watershed, N rate to meet yield goal;
    2. Manure applied in late winter/early spring to bottom 1/2 of the watershed, N rate to meet yield goal;
    3. Commercial fertilizer (N and P) to meet yield goal.
- A no-cost extension was approved by Dr. Van Kelley and has been processed, extending the end project date to February 29, 2016.

Source water implications associated with the current Black Hills mountain pine-beetle infestation

Basic Information

Title:	Source water implications associated with the current Black Hills mountain pine-beetle infestation
Project Number:	2014SD237B
Start Date:	3/1/2014
End Date:	9/21/2015
Funding Source:	104B
Congressional District:	South Dakota 1st
Research Category:	Water Quality
Focus Category:	Surface Water, Water Supply, Management and Planning
Descriptors:	None
Principal Investigators:	James Stone, John Stamm

Publications

1. Vik, E., Stone, J.J., 2015. Potential organic carbon exports within the upper Rapid Creek watershed due to the current mountain pine beetle outbreak. Presented at the South Dakota School of Mines Research Symposium Poster Presentation, Rapid City, SD April 2015
2. Vik, E., Stone, J.J., Kenner, S., Sieverding, H., Kunza, L., Stamm, J. 2015. Potential organic carbon exports within the upper Rapid Creek watershed due to the current mountain pine beetle outbreak. Presented at the 2015 Western South Dakota Hydrology Conference, Rapid City, SD, April 2015
3. Stone, J., 2016 Potential organic carbon exports within the upper Rapid Creek watershed due to the current mountain pine beetle outbreak - targeting Journal of Environmental Quality.

South Dakota USGS 104B 2014 Annual Report

Project Title: Potential organic carbon exports within the upper Rapid Creek watershed due to the current mountain pine beetle outbreak

Investigators: Dr. James Stone, South Dakota School of Mines and Technology
Erik Vik, South Dakota School of Mines and Technology
Dr. Scott Kenner, South Dakota School of Mines and Technology
Dr. Lisa Kunza, South Dakota School of Mines and Technology
Heidi Sieverding, South Dakota School of Mines and Technology
Dr. John Stamm, USGS, South Dakota Water Science Center

Introduction:

The following report addresses the progress to date and findings of significance related to the project titled "Potential organic carbon exports within the upper Rapid Creek watershed due to the current mountain pine beetle outbreak" during the funding period of April 2014 to May 2015. Funding for this project has supported research efforts examining natural organic matter (NOM) increases and surface water quality changes taking place in the upper reaches of the Rapid Creek watershed.

Background:

The current mountain pine beetle (MPB) infestation taking place in the Black Hills of South Dakota has impacted over 174,000 hectares (430,000 acres) of forested landscape. Each year, 30,000 – 40,000 hectares (75,000 – 100,000 acres) of forested land becomes infested (Thom, 2014). Close proximity of ponderosa pine trees and tree stress induced by competition, have created an environment well suited for beetle infestation.

Studies focusing on lodgepole pine (*Pinus contorta)* forests throughout the Western United States have shown that excessive tree litter resulting from MPB infestation is causing increasing levels of organic carbon in mountain watershed streams. In addition, decaying tree litter may be leaching carbon with a much higher potential of producing harmful disinfection byproducts when exposed to chlorination in municipal water treatment centers (Mikkelson et al., 2013). Edburg et al. (2012) describes that additions of carbon from fallen branches, along with labile carbon inputs from fresh litter and root exudates may lead to very large stores of carbon in groundwater resources. This will likely contribute to surface source water organic carbon content. Although research examining MPB impact on lodgepole pine forests, primarily in the Western United States and Canada (Edburg et al., 2012), show that MPB infestation is causing changes to surface water chemistry, particularly NOM and TOC (Mikkelson, Dickenson, Maxwell, McCray, Sharp, 2012; Mikkelson et al., 2013; Clow, Rhoades, Briggs, Caldwell, Lewis Jr., 2011) very little work has been done examining MPB effects on source water quality in ponderosa pine dominated watersheds. Moreover, previous studies have primarily examined sub-alpine watersheds dominated by snowmelt, rather than rainwater runoff. Watersheds in the Black Hills of South

Dakota are unique in that they are primarily ponderosa pine dominant, with runoff primarily caused by rain events, rather than snow melt. Conflicting results from previous studies, completed in different regions, suggests that hydrologic and water quality impacts due to MPB infestations cannot be generalized (Mikkelson et al, 2013).

Research Objectives:

This research aims to examine surface water NOM concentrations, including dissolved organic carbon (DOC) and total organic carbon (TOC), and to develop an understanding of how these water quality indicators may be changing due to degradation of ponderosa pine *(Pinus ponderosa)* forests, due to MPB infestation. Specific ultraviolet absorption (SUVA), parallel factor analysis (PARAFAC), and empirical predictive DBP formation methods examined by Chowdhury et al., 2009, will be used to develop an understanding of the disinfection byproduct formation potential of this carbon.

Analysis of the following additional water quality parameters will also be used to determine the following surface water quality:

- Hardness, calcium, magnesium, alkalinity, sodium, chloride, potassium, sulfate

From these water quality findings, an understanding of ponderosa pine watershed response to MPB infestation will be achieved, and should result in application to to other communities utilizing surface water from similar ponderosa pine dominated watersheds.

Methodology:

This study focuses on defining water quality changes taking place in the upper reaches of the Rapid Creek watershed. This area, near Rochford and Silver City, SD, marks the headwaters of Rapid Creek, a primary source water for Rapid City, and other communities throughout the Black Hills. This area has experienced severe MPB impact since infestation began. Figure 1 below shows the Rapid Creek watershed with the primary area of interest.

Sampling were conducted from sites along Rapid Creek, Castle Creek, and Rhoads Fork Spring. Preliminary sampling site locations are displayed in Figure 1. At each location, three samples were collected for lab analysis. The first sample was unfiltered and unacidified, and used for hardness, calcium, magnesium, alkalinity, sulfate, chloride, and sodium analysis. The second sample was used for TOC analysis, and acidified with 1 mL of 2N HCl to remove inorganic carbon, and to eliminate any microbial populations, which consume organic carbon within the sample. The final sample was used for DOC analysis, and acidified like the previous sample, and filtered using Whatman glass micro-fiber 1.5 μm filters to remove particulate organic material, leaving only the dissolved portion. During the sampling trips, samples were stored in a cooler and placed in a dark refrigerator once back in the lab.

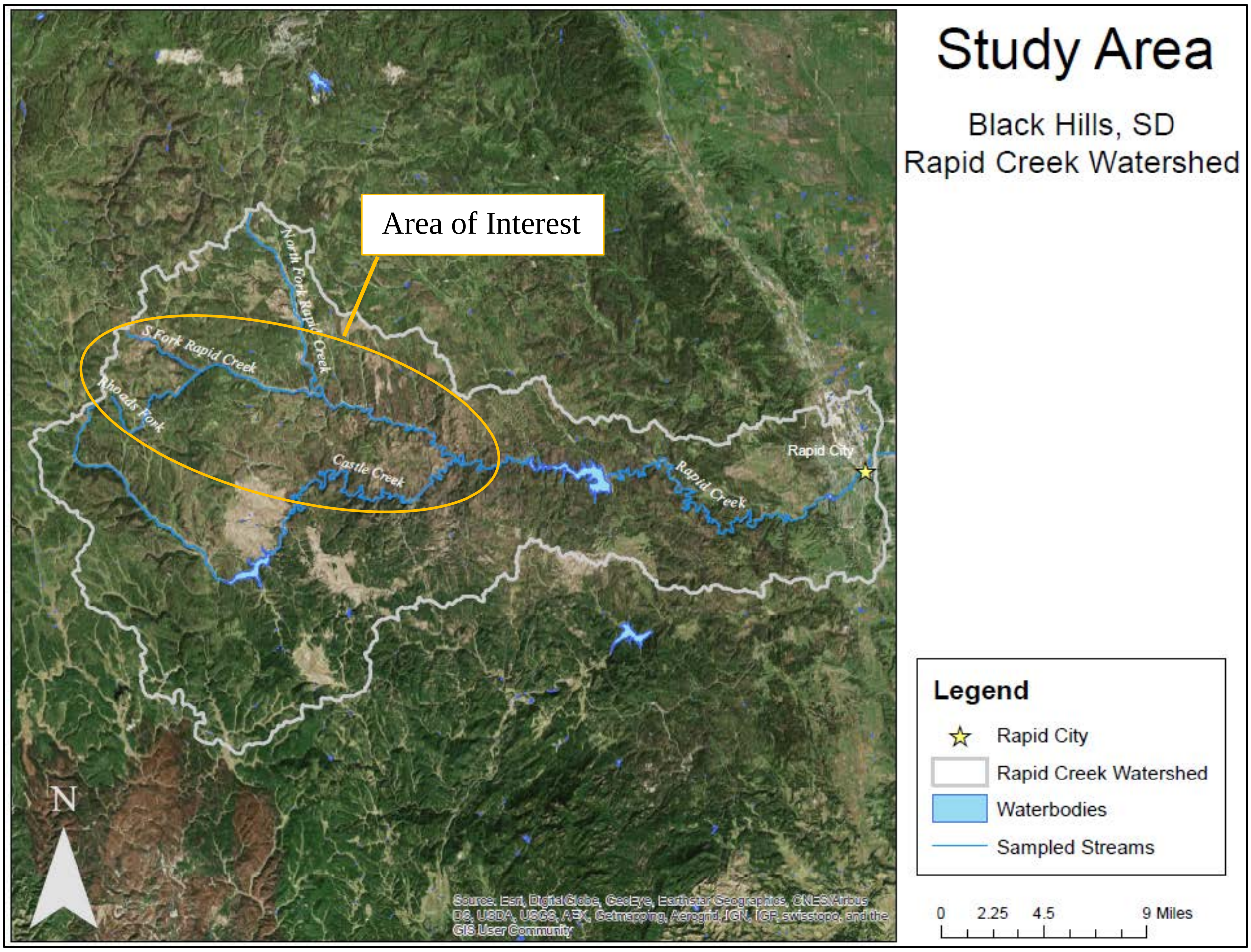

Figure 1: Area of Interest

Lab analysis for TOC, DOC, alkalinity, total/calcium/magnesium hardness, calcium, magnesium, chloride, potassium, sulfate, and sodium concentrations will be conducted. TOC concentrations were found using a TOC-L CSH/N TOC analyzer from unfiltered, acid preserved samples. DOC were measured using a Shimadzu 1601 spectrophotometer (UV-Vis) at wavelengths of 288 nm and 254 nm from filtered and acid preserved samples. Concentrations for the remaining water quality parameters were determined using Hach reagent methods, and a Hach DR2400 spectrometer. SUVA measurements were conducted by normalizing UV-Vis absorbance at 254 nm by DOC measurements, and PARAFAC analysis were conducted with a Horiba Aqualog machine.

Preliminary Findings:

In September of 2014, samples from the upper areas of Rapid Creek, near Silver City and Rochford, SD were collected. 18 samples from Rapid Creek and small tributaries emptying into Rapid Creek, were analyzed for DOC using a Shimadzu 1601 UV-Vis instrument. The results showed DOC levels ranging between 2 and 20 mg/L. Many of these levels are much higher than those typically seen in MPB impacted watersheds of Colorado, (Mikkelson et al., 2013) which show DOC levels closer to a maximum of 5 mg/L. The higher observed DOC levels, seen in the Black Hills could be the result of differences in tree litter decomposition between lodgepole and ponderosa pine forests. Figure 2 below displays the average DOC concentration, from each sample locations, with MPB impact from 2009 – 2013. The remainder of the analytical results have yet to be completed.

To examine how current DOC levels in the Black Hills compare with times of minimal or no MPB impact, the preliminary results developed from the first sampling event were compared with DOC concentrations measured in 2001 and 2002 for an Assessment of the upper Rapid Creek watershed (Kenner et al., 2004). The comparison focuses only on samples near the confluence of the North and South Forks of Rapid Creek, because previous sampling was limited to this area. The comparison shows over twice the concentration of DOC from 2001-2002 to 2014, which indicates MPB impact and tree degradation is contributing carbon to surface waters in the Black Hills. This comparison is displayed in Figure 3.

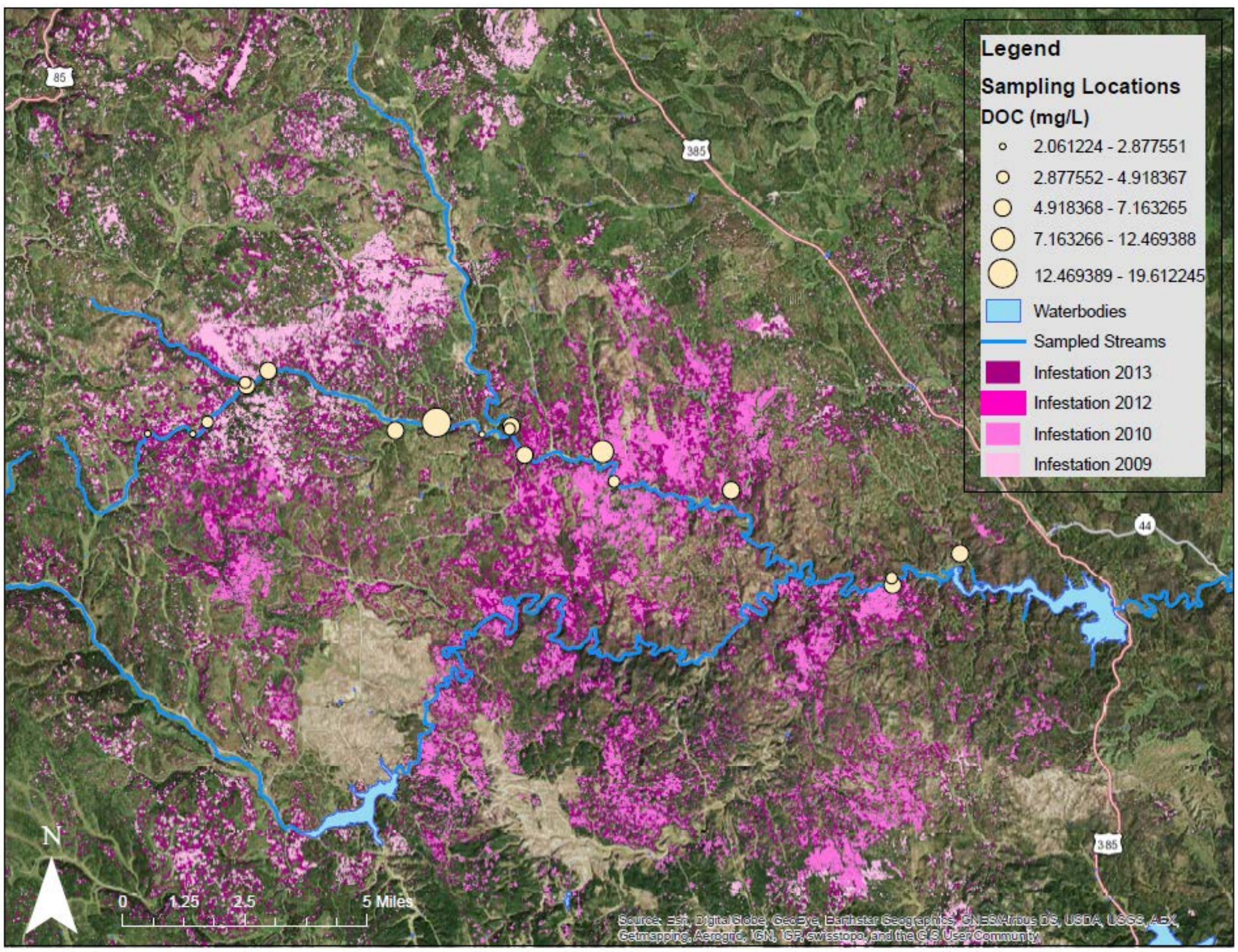

Figure 2: Preliminary sampling DOC concentrations

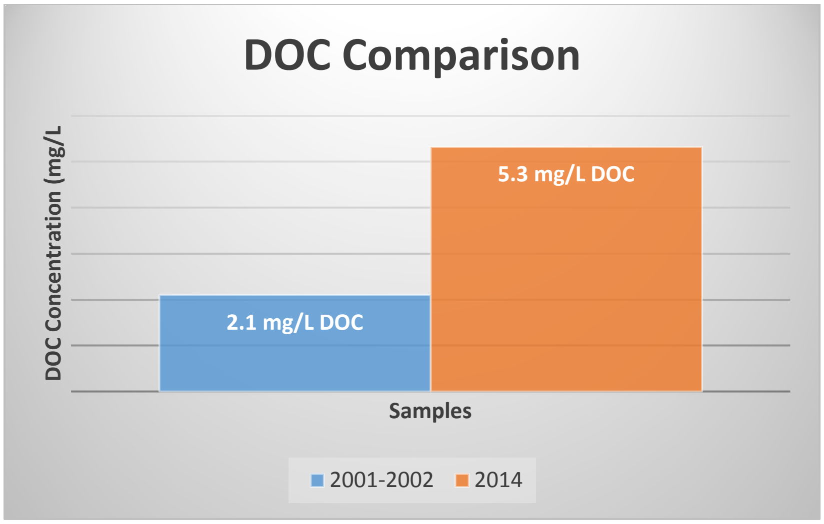

Figure 3: DOC comparison

Path Forward/Schedule:

Sampling will be completed from five main sampling events scheduled throughout the spring, summer, and fall months of 2015. Sampling dates are scheduled only during warmer months, primarily to ensure that areas of interest are accessible, but also to take into account the increased microbial decomposition of carbon which takes place during warmer periods of the year. Sampling dates are scheduled at times to reflect runoff variability, which will reflect variable organic carbon content in surface water. It is expected that heavy precipitation during the spring will result in the largest organic carbon input into surface water. From these sampling events, any temporal shifts in carbon input in MPB effected areas due to variable runoff can be observed. Samples will be analyzed within 1 month of sample collection.

Currently, all research is scheduled to be finished by December of 2015. Sampling dates are scheduled throughout the spring, summer, and fall of 2015, to reflect variations in runoff due to precipitation.

Summary:

To date, ArcGIS has been used to determine optimum site location, and preliminary DOC and general water chemistry analysis has been completed. DOC analysis was completed with a Shimadzu 1601 UV-Vis spectrophotometer, and general water chemistry analysis was completed using Hach reagent methods and a Hach DR2400 spectrometer. Pending analytical analysis will include TOC analysis and carbon characterization using the SUVA, PARAFAC, and DBP formation predictive methods.

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Information Transfer Program Introduction

The Information Transfer Program includes public outreach, interpretation of laboratory analysis results, active participation in the annual Dakotafest Farm Show which hosts 30-40,000 people throughout the three-day event, Ag PhD Hefty Field Day, steering committee representation and leading involvement in the Big Sioux Water Festival hosting 1,100 fourth grade students and in The Eastern South Dakota Water Conference, which is the largest water conference in Eastern South Dakota with around 200 participants, interactions with extension agents and local, state and federal agencies, participation and presentations at regional and national conferences, youth education, adult education and university student training and education. Publications, such as pamphlets, educational materials, reports and peer-reviewed journal entries are made available in paper format and electronic through the Institute's website and are designed to support the mission of the Institute.

South Dakota Water Resources Institute FY2014 Information Transfer Program

Basic Information

Title:	South Dakota Water Resources Institute FY2014 Information Transfer Program
Project Number:	2014SD238B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	South Dakota 1st
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, Conservation
Descriptors:	None
Principal Investigators:	Van Kelley, Kevin Dalsted

Publications

1. Andresen, J., J. Angel, P. Guinan, D. Niyogi, and D. Todey. 2014. "U2U Project Update & Tools." 39th Annual Meeting of the American Association of State Climatologists. Stevenson, WA.
2. Angel, J.R. D. P. Todey, R. Massey, M. Widhalm, L. L. Biehl, J. Andresen, D. Niyogi, C. Song, and B. Raub, 2014: The U2U Decision Support Tool for Corn Growing Degree Days. 21st Conf. on Applied Climatology, American Meteorological Society. Westminster, CO.
3. Angel, J., Todey, D.P., Massey, R., Widhalm, M., Biehl, L.L., Andresen. 2014. "Dealing with Climate Change and Variability in the Growing Season: A U2U Decision Support Tool for Central United States Corn Producers Based on Corn Growing Degree Days." 2014 American Geophysical Union Fall Meeting. San Francisco, CA.
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5. Kluck, D.R. and D. P. Todey, 2014: Providing Regional Climate Services Across the North Central U.S. 21st Conf. on Applied Climatology, American Meteorological Society. Westminster, CO.
6. Karki, G., C. Hay, J. Kjaersgaard, and T. Trooien. 2014. Design drainage intensity for eastern South Dakota. ASABE Paper No. 141914059. St. Joseph, Mich.: ASABE. Karki, G., C. Hay, T. Trooien, and J. Kjaersgaard. 2014. Calibration of DRAINMOD in South Dakota for Houdek soil series (state soil of South Dakota). ASABE Paper No. SD14-065. St. Joseph, Mich.: ASABE.
7. Khand, K., J. Kjaersgaard, C. Hay, and X. Jia. 2014. Estimating evapotranspiration from drained and undrained agricultural fields using remote sensing. ASABE Paper No. 1829687. St. Joseph, Mich.: ASABE.
8. Kjaersgaard, J., K. Khand†, C. Hay, and X. Jia. 2014. Estimating evapotranspiration from fields with and without tile drainage using remote sensing. World Environmental and Water Resources Congress 2014: pp. 1745-1753. doi: 10.1061/9780784413548.173
9. Partheeban, C., J. Kjaersgaard, C. Hay, and T. Trooien. 2014. Demonstrating the nitrogen-removal effectiveness of denitrifying bioreactors for improved drainage water management in South Dakota. ASABE Paper No. 141911325. St. Joseph, Mich.: ASABE.
10. Partheeban, C., J. Kjaersgaard, C. Hay, and T. Trooien. 2014. A review of the factors controlling the performance of denitrifying woodchip bioreactors. ASABE Paper No. SD14-029. St. Joseph, Mich.: ASABE.

11. Rasoeu, A. N., J. Kjaersgaard, T. Trooien, and C. Hay. 2014. Weather data quality control from six weather stations in South Africa surrounding Lesotho and ET mapping: The process in sustainability assessment and design criteria for irrigation for Lesotho. ASABE Paper No. SD14-015. St. Joseph, Mich.: ASABE.
12. Todey, D.T., D. R. Kluck, T. Haigh, J. R. Angel, and B. Fuchs, 2014: Regional Climate Services Information Delivery under Climate Extremes — Webinar Series and Evaluation. 21st Conf. on Applied Climatology, American Meteorological Society. Westminster, CO.
13. Widhalm, M., Andresen, J., Angel, J., Carlton, S., Haigh, T., Prokopy, L.S., and D.P. Todey. 2014. "How the 2012 drought affected agricultural advisors' climate risk perceptions and climate changes beliefs." 94th Annual Meeting of the American Meteorological Society. Atlanta, GA.
14. O'Neill, M., Online Sources of Geospatial Data, South Dakota Statewide Geospatial Conference, October 14-15, 2014
15. Khand, K., J. Kjaersgaard, and C. Hay. 2014. Evaluating impacts of subsurface drainage on evapotranspiration using remote sensing. 15th Annual Iowa-Minnesota-South Dakota Drainage Research Forum, Ames, Iowa. 18 Nov. [Invited presentation—Hay]
16. Edwards, L., C. Hay, and J. Kjaersgaard. 2014. Water use demand for corn in northeastern South Dakota. 31st Conference on Agricultural and Forest Meteorology, Portland, Ore. 12–15 May. [Oral presentation—Edwards]
17. Kjaersgaard, J., K. Khand, and C. Hay. 2014. Estimating impacts of tile drainage on crop consumptive water use. Western South Dakota Hydrology Conference, Rapid City, S.D. 9 April. [Oral presentation—Kjaersgaard]
18. Partheeban, C., G. Karki, K. Khand, S. Cortus, J. Kjaersgaard, C. Hay, and T. Trooien. 2014. Calibration of an AgriDrain control structure by using generalized "V" notch weir equation for flow measurement. Western South Dakota Hydrology Conference, Rapid City, S.D., 9 April. [Oral presentation—Partheeban]
19. Partheeban, C., J. Kjaersgaard, C. Hay, and T. Trooien. 2014. A review of agricultural practices and technologies to reduce the nitrate nitrogen load in tile drainage water. The 8th International Student Prairie Conference on Environmental Issues. Fargo, N.D., 6–8 Aug. [Oral Presentation—Partheeban]

SDWRI FY 2014 Information Transfer Program
South Dakota Water Resources Institute

PUBLIC OUTREACH

Public outreach and dissemination of research results are cornerstones of the South Dakota Water Resources Institute's (SDWRI) Information Transfer Program. The Institute distributes information through a variety of outlets, including interactive information via the Internet, pamphlets and reports, direct personal communication, hands-on demonstrations and through presentations and discussions at meetings, symposia and conferences. In addition, the SD WRI actively uses its Facebook page for two-way communication on water-related topics. These outlets are described below.

Water News Newsletter

The South Dakota Water Resources Institute *Water News* quarterly newsletter is in its eleventh year of publication. Water-related research including updates on present projects, notification of requests for proposals, state-wide water conditions, conferences, and youth activities are common topics featured in each issue of the newsletter.

The newsletter is an effective method to disseminate information about activities in which the Institute participates, funds, and promotes. The newsletter is distributed at no cost via e-mail to nearly 200 subscribers across the United States. Current and past issues of the newsletter are available through the SDWRI website (http://www.sdstate.edu/abe/wri/newsletters/index.cfm) in PDF format. The website additionally has a subscription request form where interested individuals can sign up to receive the newsletter.

SDWRI Website

During the past years, substantial efforts have gone into updating and redesigning the SDWRI website which is accessible through http://www.sdstate.edu/abe/wri/. The website continues to be updated to contain information relating to water resources, current and past research projects, reference material and extension publications. The website content is updated to reflect current conditions relating to water issues, such as water quality impact during drought situations. Since redesigning the website, the Institute has actively used the website as the entry portal relaying information relating to the Institute and water topics. As a result, we continue to see increased traffic to the website. One feature of the SD WRI website is it allows users access to updated links which include publications and on-line tools to help diagnose and treat many water quality problems. The site allows the public access to information about the activities of the Institute, gather information on specific water quality problems, learn about recent research results and links with other water resource related information available on the Internet. The "Research Projects" section of the SD WRI web contains past and present research projects, highlighting the Institute's commitment to improving water quality. An extensive library of information relating to water quality has been developed and continues to be updated on-line.

SDWRI Facebook page

The SDWRI maintains a Facebook page where information of relevance and importance to the SDWRI is posted. News releases are commonly posted to the SDWRI Facebook before other news outlets. The site currently has 86 likes and the most common age group is 25-34 years old.

Water quality analysis interpretation

SD WRI staff continues to provide interpretation of analysis and recommendations for use of water samples submitted for analysis. Assistance to individual water users in identifying and solving water quality problems is a priority of the Institute's Information Transfer Program. Interpretation of analysis and recommendations for suitability of use is produced for water samples submitted for livestock suitability, irrigation, lawn and garden, household, farmstead, heat pump, rural runoff, fish culture, and land application of waste. Printed publications and on-line information addressing specific water quality problems are relayed to lab customers to facilitate public awareness and promote education. SDWRI conducted approximately 45 interpretations during the reporting year.

Eastern South Dakota Water Conference

SDWRI staff chaired the eighth annual Eastern South Dakota Water Conference (ESDWC) held on October 29, 2014 to provide a forum for water professionals to interact and share ideas. Water is an important piece of the economic future of South Dakota, and this conference serves as a mechanism to educate participants on this resource. Sessions throughout the conference offered information important to a wide array of stakeholders including engineers, industry, public officials, agricultural producers, and conservation groups. Speakers highlighted to importance of the scientific method to determine the state of our water resources. The conference abstracts are available at the SDWRI's website at http://www.sdstate.edu/abe/wri/activities/ESDWC/2014-presentations.cfm

The goal of the 2014 Eastern South Dakota Water Conference was to bring together federal, state, and local governments, along with university and citizen insights. The event, in its sixth year, and included speakers and presenters from South Dakota State University , South Dakota School of Mines and Technology, University of South Dakota, US Geological Survey, South Dakota Department of Environment and Natural Resources, North Dakota State University, RESPEC Consulting and many others.

The call for abstracts was released in June 2014. Attendees registered and submitted their conference payment directly through the conference website hosted by the website. A registration fee of $65 was charged for individuals attending the 2014 ESDWC in a professional capacity. Students and citizens attending the conference in a non-professional capacity attended for free. 65 attendees registered for the conference and an estimated additional 60 non-registered individuals (mostly students) attended.

A poster competition for college students was held in which seven student posters were presented. The posters were assessed by 3 judges, who scored each poster and provided written feedback to the student presenters. A first prize of $200 and a second price of $100 were awarded to the two highest ranked poster presentations.

Ag PhD Hefty Field Day

For the past 3 years SDWRI has participated in AG PhD Hefty Field Day in Baltic South Dakota. The goal of Ag PhD Field Day is for the farmer to learn as much as he can in one day about new and current technologies to increase profits and yields on farmer's fields. There are lots of field plots and demos, educational sessions and champs from across the country speaking about their strategies. There were 9,000 attendees in 2014 and farmers from 26 states, 2 Canadian provinces, and several other foreign countries. Onsite we had a live bioreactor that draws quite a crowd each year along with a drainage water management/subirrigator model that is displayed in our tent.

AGENCY INTERACTIONS

The SDWRI Information Transfer program includes interaction with local, state, and federal agencies in the discussions of water-related problems in South Dakota and the development of the processes necessary to solve these problems. One of the most productive agency interactions is with the state Non-Point Source (NPS) Task Force, where the SDWRI is represented as a non-core member. The NPS Task Force is administered by the SD Department of Environment and Natural Resources which coordinates, recommends, and funds research and information projects relating to non-point water pollution sources. Participation on the NPS Task Force allows SDWRI input on non-point source projects funded through the task force and has provided support for research in several key areas such as soil nutrient management, agricultural water management, biomonitoring, and lake research. Many of the information transfer efforts of the Institute are cooperative efforts with the other state-wide and regional entities that serve on the Task Force.

SDWRI personnel additionally served on several technical committees and boards, including

- Member of the AmericaView Board of Directors
- Steering Committee for the National eXtension Conference
- Steering Committee for the Big Sioux Water Festival
- Steering Committee for the ASABE Sectional Meeting
- Collaborated on organization of American Association of State Climatologists Annual Meeting as a member of executive committee of the organization

  Several other local, state and federal agencies conduct cooperative research with SDWRI or contribute funding for research. Feedback to these agencies is often given in the form of reports and presentations at state meetings, service through committees and local boards, and public informational meetings for non-point source and research projects.

YOUTH EDUCATION

Non-point source pollution contributes to the loss of beneficial uses in many impaired water bodies in South Dakota. An important part of reducing non-point pollution is modifying the behavior of people living in watersheds through education. Programs designed to educate youth about how their activities affect water is important because attitudes regarding pollution and the human activities that cause it are formed early in life. For these reasons, Youth Education is an important component of SD WRI's Information Transfer Program.

Big Sioux Water Festival

Water Festivals provide an opportunity for fourth grade students to learn about water. SDWRI personnel were part of the organizing committee for the 2014 Big Sioux Water Festival held on May 13, 2014 with 1050 fourth grade students from eastern South Dakota participating. SD WRI was responsible for coordination of volunteers and helpers, and co-coordinating the exhibit hall.

Eastern South Dakota Science and Engineering Fair

Staff from the SD WRI served as judges at the annual Eastern South Dakota Science and Engineering Fair where 650 middle and high school students showcase projects scientific and creative ideas. The students test theories, perform experiments, test theories and learn about the scientific process. During the fair, the judges have the opportunity to discuss the students' projects and what they have learned from the experiments.

ADULT EDUCATION

As part of SDWRI's outreach to the agricultural community, staff hosted a booth at Farmfest and at DakotaFest, each a three-day agricultural fair held in August each year near Redwood Falls, MN and Mitchell, SD, which each draws approximately 30,000 people. A selection of literature an displays regarding water quality is available for distribution and SDWRI staff members field a variety of questions concerning water quality and current research for farm and ranch families. SDWRI staff also hosted a booth at the AgPhD field day held on July 24 near Baltic, SD and the Conservation Connection day held at Bramble Park Zoo in Watertown, SD.

SD WRI personnel additionally participated in and presented at several regional and national meetings and conferences, including:

Conference Name	Organizing Organization	Location	Date
South Dakota Statewide Geospatial Conference	SD View	Mitchell, SD	10/14-15/ 2014
Eastern South Dakota Water Conference	South Dakota Water Resources Institute	Brookings, SD	10/29 2014
National eXtension Conference	NEDA	Sacramento, CA	3/24-27/2014
Western SD Hydrology Conference	USGS	Rapid City, SD	4/9/2014

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	2	0	0	0	2
Ph.D.	2	0	0	0	2
Post-Doc.	0	0	0	0	0
Total	6	0	0	0	6

Notable Awards and Achievements